of
Resources
Ontario

AN OVERVIEW OF THE NORTHEASTERN REGION FOREST LAND PRODUCTIVITY SURVEY GROWTH AND YIELD PROGRAM

CENTRAL ONTARIO FOREST
TECHNOLOGY DEVELOPMENT UNIT

[redacted]

AN OVERVIEW OF THE NORTHEASTERN REGION FOREST LAND PRODUCTIVITY SURVEY GROWTH AND YIELD PROGRAM

prepared by

H. M. Kershaw
Devlin Consulting Services

for the

Central Ontario Forest Technology Development Unit
Ontario Ministry of Natural Resources
North Bay

Technical Report No. 8
December 1989

EXECUTIVE SUMMARY

The Forest Land Productivity Survey (FLaPS) of the Northeastern Region, formally initiated in 1977, consists of a continuing inventory of the surficial deposits and soils in the NE Region and a forest yield survey based on stem analysis of mean basal area trees of well-stocked natural forest stands. The program was designed to separate the 'poor sites' from the 'intermediate' and 'good' sites at a regional scale within a four year maximum time frame. The growth and yield component was to quantify, in broad regional terms, the "productive" capacity of these site (soil) types by species.

The FLaPS program consisted of four distinct phases (Heikurinen and Kershaw 1986, p. 96):

1. the review of existing land inventories in the region and an assessment of their suitability as a regional data base (carried out by Mr. C. Benson, Faculty of Forestry, Lakehead University);

2. the delineation and description of an inventory of homogeneous landform-based terrain units for the region on 114 1:50,000 scale National Topographic Series base maps (completed 1980);

3. the production of soils-and-site related yield tables for major commercial coniferous tree species and poplar found in the region and grouped according to site region (Hills 1952); and,

4. the delineation and description of homogeneous land-based forest soil mapping units on 1:15,840 scale aerial photographs and subsequent mapping for selected areas [produced on 1:20,000 scale Ontario Basic Mapping (O.B.M.) following the designation of this map base for the province].

Additions to the initial surveys were completed as funds and priorities permitted. Additions included an assessment of white birch growth and yield in 1984 with a focus on 'better sites' near the transitional zone between site regions 4E and 5E (Hills 1960). A preliminary stem analysis procedure was initiated in 1984 to develop a methodology for determining a site yield indicator for tolerant hardwoods for

integration in the Forest Management Potential (FOMAP) program. The program did not receive funding and was never completed.

The Prime Site Management (PRISMA) program for the NE Region, designed to focus management effort (human and financial resources) on more productive and more cost-effective forest land units for management, was built on the FLaPS soil and growth and yield data base. Products based on the growth and yield data included the species selection matrices used to map forest productivity at a broad regional scale, the forest soil growth indicator matrices for broad comparison of maximum mean annual increments of commercial tree species in the region, and the forest management potential map and matrix which provided a broad regional tool for mapping four levels of management potential for the region. Pressures have increased for economic evaluations of management decisions and site-specific data associated with the environmental assessment requirements for timber management planning and operations. Therefore the data set has most recently been applied in silvicultural alternative assessment models and a harvesting allocation model. The species selection matrices formed the backbone of these applications. The application at this local level is beyond the original scope of the FLaPS growth and yield data base. This has led to the need for reviewing the methods used to collect and analyze the growth and yield data, for assessing the reliability of the data, and for evaluating appropriate applications. In this author's opinion the species selection matrices which assign a site class or yield curve to a set of site parameters should be reevaluated and refined prior to any further development of applications.

This review provides a summary of the development of the FLaPS growth and yield data base and related applications, highlights past reviews of the program and related recommendations, and summarizes documented assumptions, limitations, and strengths of the data base. Seventeen different projects collecting or summarizing the FLaPS growth and yield data were reviewed and briefly summarized. A lengthier review of the original data collection and analysis of the bulk of the NE Region growth and yield data from 1979-81 is included. A summary of the primary applications of the data is included. Pilot projects integrating growth and yield matrices with soil data based in geographic applications are excluded from the review.

As indicated the FLaPS program was designed as a 'yardstick' measure of productivity of major commercial tree species in the NE Region by soil type and site region. Soil/site parameters initially selected for describing soil types were mode of deposition, soil texture, soil depth, soil moisture, topography and liminess. Site type was later defined in terms of soil texture, depth and moisture regime. Parameter classes were defined and are documented in the Northeastern Regional Forest Site Evaluation Manual (1988). Initial stem analysis measurements were done manually with a compound microscope and ruler. More recent stem analysis was performed on a digitizer linked to a 'Radio Shack colour computer' and using a provincial TRIM hardware software package.

The primary criticisms of the program which have been highlighted in the past involve the limited data set used to develop the stand density curve and the quality of the original soil data collected at each growth and yield plot. Secondary limitations are listed in the body of the report by project and are summarized in Section 6: Documented Limitations and Recommendations. More recently there have been concerns that data applications are at a local site-specific level beyond the 'design capacity' of the data base.

Studies to test the reliability of predictions based on the data set have been limited in scope and focus. They include the analysis of full plot data to evaluate how well the tree of quadratic mean basal area (used to generate the FLaPS growth and yield tables) represents plot yield. These preliminary results based on a small sample indicated that it was a reasonable indictor of mature stand yield. Both portions and complete sets of the original tree data set have been reanalyzed by several project foresters. Methods for establishing curves through the height-over-age and volume-over-age data and for grouping trees into site classes have varied from a completely manual subjective approach to curve fitting using regression analysis.

Surveys to determine the reliability of the soil data related to the growth and yield data have been conducted to a limited extent. The results from the surveys were never integrated into the computer programs which regrouped data into site classes. Application models were revised only to a limited extent in response to audit results, because of other priorities.

Staff turnover in the growth and yield program was high. Data and documentation of projects related to the program are scattered. The growth and yield data are currently on file at the Central Ontario Forest Technology Development Unit in North Bay, retrievable from a TRS-80 Model 16 computer. The systems officer is in the process of converting files to askii format. At the time of writing the computer needed repairs and no summary file listings of the existing data set could be generated. Hand-written documentation is scattered in organized and unorganized files, reports in the library (NE Region) and in binder format on book shelves in the NE Regional office. Field data and preliminary computer printouts are filed by species and site region in filing cabinets in the regional office. The bulk of the computer programs used to analyze the data are well-documented. They are written in a variety of languages for a variety of computer hardware.

ACKNOWLEDGEMENTS

The content of this report has been reviewed by

Al Barauskas, Timber Management Planning Specialist,
Sherry Hambly, Regional Ecologist,
Harri Liljalehto, Silviculture Specialist, and
Dave Heaman, Assistant Silviculture Specialist,
Northeastern Region, Sudbury;

Chris Leale, Forester-in-Training, Kirkland Lake District,

Fred Pinto, Conifer Program Forester, and
Martin Focken, Project Forester, Central Ontario Forest Technology Development Unit, North Bay.

TABLE OF CONTENTS

LIST OF FIGURES

SECTION 1: PURPOSE AND OBJECTIVES OF NORTHEASTERN REGION'S GROWTH AND YIELD PROGRAM

1.1 DESCRIPTION AND OVERVIEW OF THE FOREST LAND PRODUCTIVITY SURVEY

The Forest Land Productivity Survey (FLaPS) of the Northeastern Region consists of a continuing inventory of the surficial deposits and soil in the NE Region and a forest yield survey. The yield survey is based on stem analysis of mean basal area trees of well stocked natural forest stands. The FLaPS program was formally initiated in 1977. Mr. W. C. Stevens, the regional forester, was concerned about the high percentage of very shallow soils and bedrock in the region where current silvicultural procedures would not be effective for regenerating harvested sites to fully stocked stands. He initiated this regional program to identify where these very shallow soil areas occurred to assist in directing regeneration efforts towards sites where forest regeneration methods would be more effective.

The program was to separate the 'poor sites' from the 'intermediate' and 'good' sites at a regional scale within a four-year maximum time frame. The smallest map unit was defined as 250 ha (Stevens, pers. comm., December 1989). The growth and yield component was to quantify, in broad regional terms, the "productive" capacity of these site (soil) types by species.

The FLaPS program consisted of four distinct phases (Heikurinen and Kershaw 1986, p. 96):

1. the review of existing land inventories in the region and an assessment of their suitability as a regional data base (carried out by Mr. C. Benson, Faculty of Forestry, Lakehead University);

2. the delineation and description of an inventory of homogeneous landform-based terrain units for the region on 114 1:50,000 scale National Topographic Series base maps (completed 1980);

3. the production of soils-and site-related yield tables for major commercial coniferous tree species and poplar found in the region and grouped according to

Hills (1952) site region: and

4. the delineation and description of homogeneous land-based forest soil mapping units on 1:15,840 scale aerial photographs and subsequent mapping for selected areas [produced on 1:20,000 scale Ontario Basic Mapping (O.B.M.) following the designation of this map base for the province].

The FLaPS program, the development of its products and applications, and later additions of other data sets were directed by the Regional Silviculturist, Mr. J. Heikurinen from 1976 to 1988. From 1980 to 1988, they were also guided by the Regional Ecologist, Ms. M. Kershaw.

Additions to the initial surveys were completed as funds and priorities permitted. In 1984 growth and yield data were collected for white birch throughout the region following a request by Wawa District for assistance in determining rotation ages for white birch for management planning. The initial data were collected in Wawa District using refinements to the basic FLaPS growth and yield procedures designed by Mr. D. Kloss, regional project forester. The regional project was carried out by Ms. L. Quist.

A preliminary stem analysis procedure was tested for tolerant hardwoods in North Bay District under the supervision of the regional ecologist. This was in response to concerns of district forest staff in Sault Ste. Marie, Blind River and North Bay about the lack of data for these species in the Forest Management Potential (FOMAP) applications. Additional hard maple and yellow birch growth and yield data were collected by the Sault Ste. Marie Job Corps program under the direction of Mr. D. Wells in subsequent years. This information is currently being reviewed, under a separate contract by the Central Ontario Forest Technology Development Unit (COFTDU), North Bay. It will not be addressed in this review.

A limited data set of tamarack (*Larix laricina* (Du Roi) K. Koch) tree cores was collected by regional staff to provide a preliminary index to the growth and yield of this species. No analysis of this data was completed.

The Prime Site Management (PriSMa) program for the NE Region, designed to focus management effort (human and financial resources) on more productive and

more cost effective forest land units, was built on the FLaPS soil and growth and yield data base. The direction and description of this program is beyond the scope of this review.

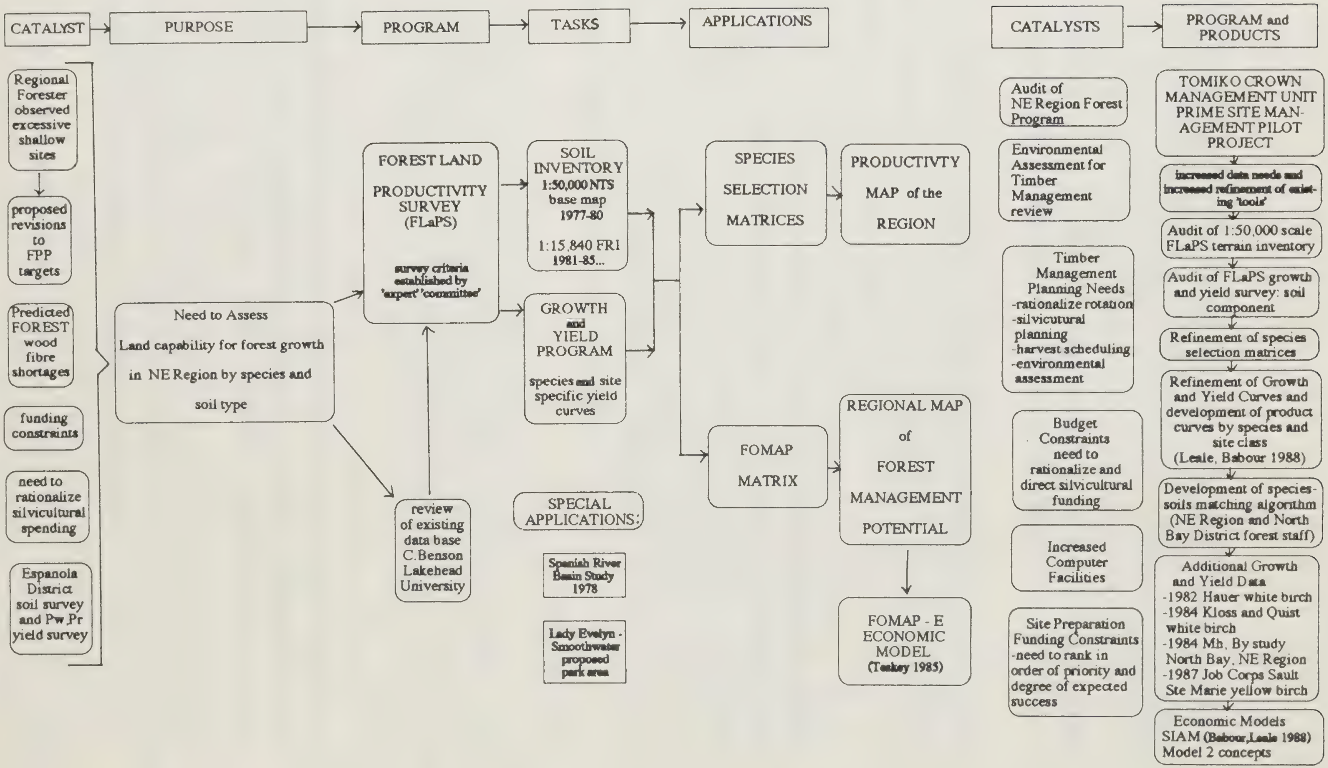
This overview will, as requested, address the growth and yield component of the FLaPS program, excluding the sugar maple and yellow birch components.

The growth and yield program was designed to estimate growth and yield of natural stands growing on recognizable land types. The objective was to relate volume growth of forest stands to soils. Site index curves were not considered appropriate for estimating stand yield. Permanent sample plots (PSP) measuring volume growth, ingrowth and mortality under dynamic stand conditions do not exist for all species of interest in the NE Region. An appropriate stratification of the region into forest systems as a basis for a permanent sample plot program was unknown. In addition, the objective of developing a data base within four years for directing investments of time and finances away from the shallow, less productive sites could not be met by establishing a permanent sample plot program. One of the longer-term objectives was to establish a system of PSPs across the region. An internal report of recommendations for establishing permanent sample plots is on file at the Regional office.

As a practical alternative to a permanent sample plot system a combination of stem analysis and single-time stand measurements was selected to meet the project objectives. This would permit the estimation of individual tree growth and of stand growth.

A number of applications were developed using the land and growth and yield data base to classify the region into the 'good', 'intermediate' and 'poor' lands for forest management investments. These are briefly discussed in section 5 of this report. They include the species selection matrices, forest soil growth indicators, productivity maps (PRODMAP), the forest management potential map and matrix (FOMAP) and three economic applications, the Forest Management Economic Priorities Model (FOMAP-E), a silvicultural investment model (SIAM), and the conceptual design for a harvest allocation model (Model II).

Figure 1. Schematic Summary of the Northeastern Region Forest Land Productivity Survey 1976 to 1988



Each application builds on the FLaPS soil and growth and yield data bases and associated tools. FOMAP introduced an ease rating (based on soil and topographic characteristics) reflecting the physical ease of managing a site and combined this with site productivity information in a matrix. This matrix provided a rating of management suitability with the four levels of "elite", "intensive", "basic", and "extensive". The matrix was designed to be used on site or to generate a map of management suitability levels from a soil or terrain map. FOMAP-E attached a set of specific silvicultural prescriptions to the FOMAP matrix (to productivity and ease classes), estimated cost components and employed a 'computer-based' model to assign management priorities to FLaPS terrain units. Recommended rotation ages for decision-making are based on the local growth and yield data set. Modelling average yields from hypothetical regeneration efforts and generating management priorities included rationalizing a potential wood supply.

SIAM (Silvicultural Investment Analysis Model) considers the existing forest as well as the potential future stands. SIAM helps foresters to compare silvicultural options. The proposed harvest allocation Model II will assist in setting harvesting priorities.

The FLaPS data base and the applications have been integrated into the management planning program. A pilot program for developing tools for this purpose is in progress in the Tomiko Crown Management Unit PriSMa pilot project in North Bay District.

1.2 PURPOSE AND OBJECTIVES

The regional Forest Land Productivity Survey (FLaPS) program was initiated one year after a soil survey and stem analysis program designed and conducted by Espanola District. The purpose of the district program was stated as follows: "in the long term, accurate soil surveys will enable Ministry research workers to produce precise yield tables for different tree species growing on each soil type mapped. This will enable the forest manager to more accurately predict timber harvesting yields under given silvicultural systems for all soil types" (Tennyson Township soil survey report, 1976).

The purpose of the FLaPS program was defined by the regional forester in a speech in 1981 as "to determine the areas which will give the greatest yield of

quality wood fibre and where the silvicultural dollar can be spent to obtain the greatest return on investment".

The objectives of the FLaPS growth and yield program can be summarized as:

Initially: 1976-1980

1. to identify and map the potential productivity of the NE Region lands for growing a natural forest within a two-year horizon (Stevens, pers. comm. 1989)

2. to develop a practical method of acquiring site-specific yield information for mature natural stands (Warren and Wood 1981)

3. to acquire site-specific yield information and to develop species-and site-specific yield curves for the major commercial tree species in the region (initially Pw, Pj, Sw, Sb, and Po) on sites where they would most likely be managed (AMIK/OMNR contract specifications, 1979) to assist in regional forest management decisions (Warren and Wood 1981);

   a) to sample a minimum of three stands of the following species in each Site District:

Species	**Site Region**	**Soil Depth**
Pw	4E, 5E	very Shallow, Shallow, Deep
Pj	3E 4E	very Shallow, Shallow, Deep
Sb	3E 4E	very Shallow, Shallow, Deep
Po	3E 4E 5E	Shallow, Deep
Sw	4E 5E	Shallow, Deep;

   b) to sample mature, well-stocked stands where the working group is the dominant or co-dominant species;

   c) to estimate stand- and site conditions by describing soil conditions, topographic location, stand density and lesser vegetation surrounding the sample tree;

4. to be able to relate growth patterns to measurable site parameters so that yield by species could be predicted for a given site (Kershaw 1984).

Early 1980's

The original objectives were expanded in the early 1980s with the conversion to a computerized data base, to include the identification and mapping of potential forest productivity and forest management potential by soil types across the region. This would serve as one guide for directing forest production policy and would provide a guide for silvicultural planning. These products became part of the NE Region's Prime Site program. Specific objectives included:

1. to test the hypothesis that higher productivity for all species would be found in the southern site region 5E, with the lowest productivity in site region 3E

2. to develop products to assist in rationalizing forest management funding allocations from a regional perspective (eg. tools for projecting future silvicultural needs, for silvicultural planning, and for comparing forest management potential across the region).

Mid 1980's:

In the mid-1980's, the FLaPS data base was reviewed for management planning applications. With increased computer capability, increased data needs related to environmental assessment and modified management planning requirements, the data base was adopted for comparing silvicultural options, for developing harvest priorities and for distributing regional silvicultural funds. The Tomiko PriSMa pilot was intended to test the effectiveness of this regional data set at a local level. This was beyond the original purpose of the data set. Two specific objectives were defined:

1. to provide a site (soil) related growth and yield data base for developing and assessing silvicultural prescriptions for forest units

2. to provide a site-related growth and yield data base for inclusion in a harvest priorities model.

1.3 BROAD PROGRAM ASSUMPTIONS

The following assumptions were inherent in the program:

1. Soil types correlate to growth and yield. Broad growth and yield classes by species can be predicted on the basis of soil types defined by soil depth, texture and moisture. Similar combinations of relief and parent material will generate similar successions of plant communities within a site region.

2. Soil types can be surveyed, mapped and described effectively and rapidly in the field by trained students and graduate foresters, soil scientists and geographers using field descriptive methods.

3. Surficial geology, soil depth, texture, moisture, topography (slope, position on slope and aspect), and stoniness are key site parameters related to tree growth and operability.

4. Growth for a species is different between site regions and site districts.

5. Yield can be estimated by volume of mature trees of mean basal area within well-stocked natural stands.

1.4 RATIONALE FOR FLAPS

The need for a soil-site specific data base for the rationalization of forest management activities was identified by the Regional forester in the early 1970s. As he indicates in a 1981 speech, "there were obviously large areas of very shallow soil or bare rock...much of it not identified in the Forest Resource Inventory...the problem became one of identifying all the sites in the region...the sites were too shallow to work silviculturally and equipment necessary for shallow site work (is) not available". He defines the purpose of the growth and yield data as "to evaluate the growth of trees on the various soil units". The regional silviculturalist designed and directed this program. He identified a need for a soils inventory and species-specific, site-specific, variable-density yield tables. These data bases were necessary to access the cost-effectiveness of alternative regional silvicultural

strategies.

More recently the needs were refined. There is a need for merchantable yield tables for comparing silvicultural alternatives, and for yield data to assist in stand allocation at the forest management unit level for management planning. With the implementation of the Environmental Assessment requirements for timber management there is also a need for local site yield information by species, stand and forest community types.

1.5 SUMMARY OF FLaPS STEM ANALYSIS PROJECTS (chronologically, excluding applications)

The following summarizes a number of FLaPS growth and yield products from between 1975 and 1988. Figure 1 on page 4 displays the relationship of many of these products to the overall FLaPS program.

1. **Espanola District Red Pine and White Pine Growth and Yield Data 1975-76:** these data were not integrated into the regional data base; single tree of mean basal area sampled at 1 m intervals and measured manually by five-year growth increments; reports on methods and results on file 11.4.6.2.3 (Tennyson Township stem analysis project 1976).

2. **NE Region Plantation Data 1977**: plots in 30- to 55-year old plantations (excluded from FLaPS data set) eg. Nairn Plantation; limited plantation data in computer files, excluded from 1988 development of growth and yield tables for natural stands; trees from plantations identified as site class "O".

3. Operational pilot project relating soil survey data to growth and yield data; carried out for Spanish River Basin (**Heikurinen and Slater 1978;** file report).

4. **AMIK** / NE Region stem analysis contract (1979-81): 1237 trees from 310 plots (established the bulk of the FLaPS growth and yield data set; final report in binder format summarizes methods and results; includes soils data summaries, height-over-age and volume-over-age curves and tables for species, site region, site classes and soil depth class; site regions combined

where limited data; includes hard-drawn curves of mean annual increment (mai), periodic annual increment (pai), gross total volume and gross merchantable volume curves by species, site class and site region (Warren and Wood 1981).

5. **Kroetsch, J. 1982** Summary of soils data and growth and yield data to redefine height-over-age and volume-over-age curves for site classes and height classes independent of the soil depth strata (file report in binder format).

6. **Kroetsch, J. 1982** Summary of red pine and white pine growth and yield data for site region 4200 and 5200 for application by Temagami District in reassessing rotation ages (file report, binder).

7. **Hauer, G. 1982.** Summary of white birch, yellow birch and hard maple growth study for Wawa district (on file, file not numbered); use of stem analysis programs 'stemdig' and 'stemvol' is documented; data stored on Model 16 TRS-80 computer; data used to construct growth curves.

8. **Teskey, S. 1983** Examination of red pine growth in site region 4200 and 5200 (file report, could not be located).

9. **NE Region 1982** Black spruce growth and yield data as part of peatland survey (data integrated with main NE Region growth and yield data set; printouts filed under spruce by site region).

10. **Niemi, C. et. al. 1984** Relocation of growth and yield plots for reanalysis of soils data (audit report on file; soils data associated with trees have not been adjusted or integrated into the site class interpretations for the NE Region growth and yield data set).

11. **Collier, R. 1984-85** Full-tree black spruce and jack pine plots in site region 3200 and jack pine plots in site region 4200 to test the effectiveness of current FLaPS growth and yield sampling methods (trees of mean basal area); data collected from Collier's studies were integrated into the NE Region data set. Reports include:

Collier, R. Dec. 1984. Procedure for coppice origin stands, NE Region file report.

Collier, R. 1985. Procedure for developing site index curves for the Forest Land Productivity Survey, NE Region file report.

Collier, R. Jan. 1985. Procedure for determining trees per hectare over time, NE Region file report.

Collier, R. March 1985. A methodology for producing forest yield tables, forest productivity survey, NE Region file report.

Collier, R. May 1985. Yield tables for jack pine growing in site Region 4E, forest productivity survey, NE Region file report.

Collier, R. June 1985. A preliminary analysis of the data collected from a jack pine stand by White River, NE Region file report.

Collier, R. June 1985. FLaPS Growth and yield procedures: a critique, NE Region file report.

12. **Kloss, D. and Wawa District 1984** (no date on report) Stem analysis of white birch for assessment of rotation ages (report filed under Growth and Yield - Weibull function).

13. **Quist, L. 1984** White birch stem analysis program, NE Region (file report; binder format; data integrated with NE Region data set).

14. **Harrow, A. and D. Heaman 1984** tree core collection of *Larix laricina* (file report not located).

15. **Reid, B. and D. Heaman 1984** Hardwood growth and yield pilot, North Bay District (file report on methods; data forwarded to the COFTDU, hardwood growth and yield project).

16. **Sault Ste. Marie Job Corps 1987** Growth and Yield stem analysis program for hard maple and yellow birch in Sault Ste. Marie District (file report on methods used; data forwarded to the COFTDU for hardwood growth and yield project).

17. **Babor, P., M. Downs and C. Leale 1988:** Computerization of NE Region data set (1970-1988) and reanalysis for application in product yield curves and economic models (hard copy of annotated height-over-age and volume-over-age curves by site region and site class with tables in binder format; data on TRS-80 Model 16 diskettes; COFTDU conversion to askii files in progress; file report on procedures and rough summaries of trees by file name, township, FRI stand number, plot number, tree letter, height class, site class and comments concerning the presence of field data and soils data; file 11.4.6.2.3). Product curves were produced from the regional data set by species, site class and site region (binder format).

SECTION 2: METHODS

2.1 SAMPLING

The sampling methods for the initial FLaPS program were designed by a steering/working committee composed of Mr. G. Pierpoint and Mr. David Bates, members of the Site Evaluation Unit at Maple, now the Ontario Forest Research Institute (OFRI), and three unit foresters from the NE Region representing the different forest types: Mr. John Vining - the boreal forest (Wawa), Mr. Bill Managhan - the hardwood forest, and Mr. H. Liljalehto representing the pine forests. Foresters who had been involved with soil and site evaluation work in other regions were consulted, notably from Atikokan District. The soil and site survey methods were designed and approved by Mr. G. Pierpoint; Mr. J. Heikurinen, the regional silviculturalist, designed and managed the growth and yield component. Because of the original purpose of the program, emphasis was placed on trees growing on shallow soils.

2.1.1 Sampling Stratification

The sampling program was designed to provide species-specific data. The initial stratification was into five working group species: jack pine (*Pinus banksiana* Lamb.), white pine (*P. strobus* L.), white spruce (*Picea glauca* (Moench) Voss), black spruce (*P. mariana* (Mill.) B.S.P.) and trembling aspen (*Populus tremuloides* Michx.). Red pine (*Pinus resinosa* Ait.) was added to the original growth and yield contract in 1979. There was difficulty in locating well-stocked natural red pine stands for sampling.

The program was expanded in 1984 to include white birch (*B. papyrifera* Marsh.), yellow birch (*Betula alleghaniensis* Britt.) and sugar maple (*Acer saccharum* Marsh.). This includes all of the major commercial tree species in the NE Region.

The NE Region was stratified by site region and site district (Hills 1960) to reflect broad climatic, physiographic and vegetation patterns. Site region is a land unit based on regional climate as reflected by the association of vegetation with landforms. Data collected within each site region were analyzed as a separate population. Insufficient sampling was conducted to assess differences between site

districts. The data were further stratified by soil depth, a parameter that could be interpreted by air photo interpretation and was expected to influence forest growth. Sites were then stratified by soil depth into very shallow (0-30 cm), shallow (30-120 cm) and deep soils (120+ cm), conforming to the broad FLaPS Terrain inventory. Emphasis was placed on selecting very shallow sites for jack pine, white pine and black spruce (AMIK/OMNR Contract specifications, 1979).

2.1.2 Distribution

Sampling was conducted in a wide geographic area. It was designed to sample in all three site regions in the NE Region. This was accomplished as displayed on Map 2 (Appendix III). A 1:506,000 scale map showing the distribution of sampling is on file in the GABS map cabinet at the regional office. One 0.5 ha plot was placed in any one FRI Stand for the original stem analysis survey. In carrying out the hard maple-yellow birch growth and yield assessment, two to four plots were located in each selected stand.

2.1.3 Sampling Techniques

1976 Espanola Stem Analysis Project

Six plots in total were established on stony, silty fine sand, stony silt loam, and stone-free silty clay loam soils. One red pine and one white pine were sampled on each soil type within a 1/10 ha circular plot. All trees were tallied by 2-inch diameter classes. Basal area of dominant and co-dominant trees was calculated separately for red pine and white pine. One tree of mean basal area for each species was destructively sampled with discs removed at 1m intervals. Five year growth increments were marked and radii measured from pith to marked growth layers.

Height-over-age curves were plotted by tree. Total tree volume was calculated by five-year intervals. Volume-over-age curves were plotted. Quadratic equations were developed using regression analysis for all data from age 25 years onwards. The curves were plotted on graphs. Current annual increment curves were developed from the derivative of the equation for volume growth by tree. These curves were compared to Plonski's 1974 index curves.

NE Regional Program (1979-1988)

Well-stocked mature stands with a component of the working group species greater than 51% were selected for sampling (Heikurinen 1985). The original survey defined a maximum of three plots per species, per depth class, per site region and site district. Areas where the species was not thought to occur or be managed were excluded. This is outlined in the 1979-81 AMIK/NE Region Ontario Ministry of Natural Resources contract specifications.

1982-88

The methods used for data collection between 1982 and 1988 were designed to address specific user needs or to test the earlier FLaPS growth and yield methods. These are discussed in Section 4: GROWTH AND YIELD REPORTS BY SPECIES AND TOPIC.

1977-1981

A 0.5 ha plot (20 m x 25 m with the long axis aligned north-south) was placed subjectively within a stand selected for sampling. Plot location criteria included:

- uniform depth class,

- working group species must exceed 51% of trees tallied in the plot,

- working group species must be dominant or co-dominant in the plot,

- 20 to 50 trees greater than 7 cm dbh must occur in the plot,

- must not extend to within 25 m of the stand boundary,

- stand age at least 80 yrs for Pw, Pr, Sb; 70 years for Sw; 60 yrs for Pj and 50 years for poplar.

All plots were marked on air photographs and numbered by site region, site district,

plot number and tree number eg. 5209 - 21 Site Region 5E, site district 09, soil depth class of the plot - 2, soil depth class of the tree 1. These were later renumbered by species (eg. Sw), township (eg. A30 for Aberdeen), site region (eg. 4), plot number (eg. 30) and tree number (eg. 04) for data entry and filing.

All trees greater than 7 cm dbh in the plot were tallied by dbh by working group species, principal secondary species and other species. All trees heights were tallied.

The diameter of the quadratic mean tree of the principal species greater than 8 cm [tree of average basal area (BA) for the principal species] was calculated using standard mensuration procedures.

Four trees closest to this mean within the plot or within 50 m of the plot and free of defect were felled, sectioned at 0.3 m, 1.3 m, and at one metre intervals to the crown. Total tree height was measured (Warren and Wood 1981, p. 1).

The distance to the nearest five neighbours of the sample trees was recorded. Distances were from the pith of the felled tree to the approximate centre of adjacent trees which form the same canopy as the sample tree. The formula used was

$$\text{average spacing} = [(dl+d2+d3+d4)/4+(d1+d2+d3+d4+d5)/5]/2$$

where d1 is the closest neighbouring tree, d2 the second closest ..... d5 the fifth-closest neighbouring tree to the sample tree.

Sections were removed at 0.3 m and at every subsequent metre for the length of the tree (Warren and Wood 1981, p.1) and total height measured.

A compound microscope was used to measure and tally five-year periodic increment along a mean radius of each disc (inside bark) of sample trees. The 1979-81 measurements were made by hand with a ruler. Tree age was defined as that of the basal disc.

Soil texture of the parent material, stratifications, hard pan, depth of A- and B horizons, presence of absence of reaction to dilute HC1 acid, stoniness class, soil

depth, soil moisture regime and rootable depth were to be recorded with 2 m of each sample tree in a 1 m deep soil pit. A sketch of the soil profile was completed. Aspect, degree of slope, position on slope and topographic class were noted for the sample plot. Ground vegetation and type of regeneration were also recorded for the plots; a total of 16 site variables were to be measured and recorded (Note: not all plots have complete soil profile descriptions).

2.1.4 Calculations

Periodic (5 yr) gross total volume increments for each sampled tree were calculated according to Smalian's formula (periodic volume increment and total tree volume increment by 5 year intervals). Volume calculations assume each section is a cylinder (and a mean basal area is calculated and multiplied by the length) except for the top section which is assumed to be a cone.

Age at each 1 m height interval was recorded and converted to a height/age measurement. Tree increment data, total volume data and age data were grouped into sampling strata. Periodic volume increment by age, total tree volume by age and tree height versus age for each sampling stratum were plotted on a common axis on semi-transparent drafting paper. A free-hand curve was drawn through the plotted points.

Specified site data (soil depth, texture, moisture) and stand data from tally sheets were transferred to graphs.

A stand density curve was developed from stand density data collected from the plots, by estimating an initial stand density based on plantation data and the experience of the regional silviculturalist. Stand density for stands exceeding the sample age was estimated by the regional silviculturalist with two field checks.

Data were originally manually recorded on tally sheets and analyzed with a programmable calculator (the program documentation is on file); files were later transferred onto a TRS-80 (Tandy Corporation) Model 16 computer. Part of the data set was then transferred to a DEC PRO 350 (Digital Electronic of Canada Corp) micro computer for analysis. Data are currently being transformed to askii files by Mr. S. Christilaw at the Central Ontario Forest Technology Development

Unit. This is to be completed by March 1990 (Christilaw, pers, comm. December 19, 1989).

2.1.5 Auditing/Checking Procedures

An audit of the stem analysis work was completed on the 1979-81 data. An audit sheet for the field plots and for the analysis was filled out for each plot. Plot location, plot tallying, and all calculations were audited. A subjective check of soils was made but no verification or modification of the soil profile description or texture was completed until the 1984 audit.

In the 1984 audit, as many plots as possible were relocated. A soil pit was dug within 1 m of each sample tree. A soil sample from each horizon was analyzed by the Ontario Forest Research Institute in Maple by sieving and hydrometer. All laboratory textures were compared to original field textures; the percentage deviation was calculated both for texture and for family particle size (Nicholson 1984). In 1988 a sample of the soils data was reexamined by the regional ecologist and moisture regime was reinterpreted to conform to revised soil moisture regime calculations for shallow soils. This review suggested a need to review all of the original soil data.

2.1.6 Assumptions and Limitations of Sampling Methods

Soils, Site and Vegetation

Soil textures determined in the field were not verified during the initial 1979-81 program. No samples were forwarded to a laboratory for soil particle size analysis. Ten percent of the plots were revisited and the soils described during 1984. This represented all the plots that could be relocated. Soil samples were collected and sent for particle size analysis to the Ontario Tree Improvement and Forest Biomass Institute in Maple. Results were summarized but never integrated into the final data set. Originally the audit was to be on a sample of the stem analysis plots. Difficulties arose relocating plots because of harvesting, missing photographs with plot locations marked on them and practical field access problems. This led to modifying the audit to sample any plots that could be found within the given time and budget.

Many of the original soil profile descriptions were incomplete and sketchy. Emphasis was placed on identifying one texture and a depth class to conform with the broad regional terrain inventory. Very few of the descriptions both measured and described the LFH layers, identified and documented texture stratifications, or consistently recorded a texture of a defined horizon (eg. parent material). Stoniness was also poorly defined. The distribution of, and depth to, coarse fragments was not made clear. Soil moisture regime was based on a chart designed for deep uniform soils, but many of the plots lay on shallow soils where the moisture regime status did not reflect the relative availability of moisture.

Surface Vegetation was not defined within a plot, no collections were made to verify identifications, and surveyors listed only those species they were familiar with. Common nomenclature was often used and species often only identified to genus. Moss and lichens were not defined by species or species groups.

Data on stand density were limited by the sampling design. Sampling was restricted to well-stocked stands based on a consultant's statement that tree height is independent of spacing only in stands of intermediate or normal stocking. Starting stand densities were established using an "expert model" approach of using the best approximation based on field observations of stands in the NE Region, a review of Plonski's density curves and extending the NER curves established using the plot data. The rationale for specific figures is not documented in the 1979-81 file reports.

General Assumptions

The following general assumptions underly the growth and yield applications of the Forest Land Productivity Survey:

1. Stand height is independent of stand density in well-stocked stands.

2. Stand density curves by species using the standard procedures defined in the methods section of this report are valid.

3. Trees of mean basal area represent the volume production potential for a given

site.

4. Stand productivity can be related to field-measurable soil and site factors.

5. Soil field texturing was reliable.

6. Tree height growth is related to soil depth, -texture and -moisture.

7. Stem analysis at 1-m intervals is a reliable method for producing height-over-age and volume-over-age curves.

8. Drawing curves by hand is a reasonable method for dividing a data set into yield classes.

9. Manual overlaying of curves to select similar curve patterns to classify into site classes is a reliable approach to grouping similar data.

2.2 INITIAL ANALYSIS OF REGIONAL DATA SET

The growth data were analyzed in two steps by Warren and Wood from 1978 to 1981: site classes were determined for each species and then yield tables were constructed for each site class.

2.2.1 Site Class Determination

In 1979 Warren and Wood (1981) reviewed alternative approaches to classifying data to meet with objectives. They recommended using physiographic parameters to group data and to produce yield tables. More specifically they outlined the following procedures.

Height-over-age curves were constructed for each tree from the stem analysis data. A multiple linear regression was attempted for relating soil properties to tree growth but abandoned because the statistical assumption of independence among independent variables was violated (eg. soil moisture is influenced by texture, depth, etc.) and the data set was too small for the analysis. The analysis fit the irregularities in the data and not the general cases. Texture, depth and moisture

were subjectively examined to determine which soil condition affected height growth and what their effects were. Soil depth was selected as the most reliable and indicative factor.

Height-over-age curves were overlain on a light table and subjectively grouped into classes of similar shapes. Individual height-over-age curves were stratified by species, site region and depth class. Trees with similar patterns of height growth were grouped and assigned a site class (Warren and Wood 1981, p.3). Site class I has the highest growth rate; II and III have lower growth rates.

2.2.2 Development of Yield Tables

Curves of gross total volume over age were calculated for each site class using data from the individual trees. The coefficient of variation was calculated for the data and 80% confidence intervals were plotted on the appropriate graphs. The resulting curves were subjectively compared to Plonski's curves (Plonski 1960).

Separate yield tables were constructed for each site class. The mean volume of all the trees in a site class was calculated for each age, the means plotted and a curve hand-fitted to them. Individual-tree volume tables were prepared from the curve. To transform individual-tree volumes to stand volumes, individual tree volumes were multiplied by stand density. Mean individual tree volumes were multiplied by corresponding stand densities to arrive at mean stand volumes. Stand density curves were derived from the plot data and from field observations of densities of young and very mature stands. Curves were hand-fitted to the means and yield tables (gross total volume) constructed using the values from the hand-fitted curves.

2.3 REANALYSIS OF ORIGINAL DATA SET 1981-89

Kroetsch completed a summary of the growth and yield data in 1981. Soil characteristics, height classes and associated site class were documented. The original curves were overlaid on a light table and regrouped as required. Summary tables of tree growth trends related to site factors by species and site region were completed (on file, NE Region, no file number). Number of plots and numbers of trees were identified. Parameters summarized include texture, moisture, depth,

aspect, position on slope, percent slope, organic matter and general comments. Sample trees are listed by District, FRI stand number, tree letter, height class, texture, depth class, moisture regime class, aspect, slope position, trees per ha, age and spacing. A summary of important site factors by species and site region is given on a separate table. A standard site region boundary was established using the township boundaries rather than the original free-hand curved boundary (Hills 1960). It was similar to the site region boundary used for seed collection. This was used for creating computer data records of the growth and yield data on the TRS-80 (Model 16, Tandy Corporation) computer (Appendix III, Map 1).

Kroetsch (1982) completed a summary of site classes by texture, moisture and depth for red pine 4E, 5E, white pine 4E and 5E, jack pine 3E, 4E and 5E, black spruce for 3E, 4E and 5E combined, white spruce 3E, 4E and 5E combined and poplar 3E and 4E combined and 5E. These are included in the binder on "classification of stem analysis typed tables, section I". Township, site district, FRI stand number, tree number (letter), height class, texture, depth, moisture, aspect, position, slope, trees per hectare, age and spacing are listed. The total number of plots and total numbers of trees are identified.

In 1984 the soils in some of the plots were resampled and the revised soil data recorded. The data were then run through a "mean-bark-diameter at breast height" program to isolate any numerical input errors, and were corrected. The mbdbh program was developed by Babor (1988). Nine trees were removed from the site region 4E data set because the data were not reliable. SAS software was used to determine the correct site class for individual tree curves.

Summaries of the 1988 reanalysis procedures are presented in the binder of the Northeastern Region Yield Tables for Major species 1988 (Leale, compiler 1988) and in annotated hand-written file notes (including Leale, unfiled 05/02/1988). A computerized listing of all trees which were on line was generated by M. Downs in 1988 and cross-checked with the original study material of 1981. Some of the trees were missing. In some plots soil data and trees were missing, some trees showed just empty disk space and some trees appeared twice under different plot numbers. Some trees had not been entered. These omissions and errors were corrected. Updated summaries were prepared; any data discrepancies were corrected. The mbdbh program was used to develop product yield curves and to

isolate any numerical and input errors in the data set. This program had no documentation (Leale, pers. comm. Feb. 1990). Errors were corrected by consulting the original field data sheets. Plantation trees were flagged and excluded from the final analysis and preparation of regional growth and yield curves by species, site class, and site region.

Density curves were established for species by site region. These curves were re-examined and 'smoothed' at the project forester's discretion. Figures from Plonski's jack pine stand data were used for establishing the older stand densities for all site classes (Leale, pers. comm. December 1989). Regressions were run for the data using SAS and curves fitted to the data where field data existed. The remainder of the density curves were fitted according to the judgement of the project forester. An initial density was set at 1500 trees/ha and an upper asymptote set at 500 trees abased on discussions with the regional silviculturalist.

Yield tables were prepared for estimates of gross total and merchantable yield by broad product types using customized computer programs. Merchantable yields include 1) gross merchantable volume (GMV), 2) portions of GMV with potential for stud lumber and 3) portions of GMV with potential for sawlog lumber. For white birch, there is an estimate of lumber yield for grade one and two logs instead of stud and sawlog lumber. For poplar there is only one lumber component: yields from eight foot bolts. Species-specific minimum top diameters and variable stump heights were used to calculate GMV. Methods are clearly outlined in the report by Leale (1988). The reader is directed to this report for specific methods of data analysis and interpretation. These tables provide the best local estimates available of yields for approximations of the existing natural forest stands. Soil data were not related to the yield curves.

SECTION 3: RESULTS AND CONCLUSIONS

3.1 REGIONAL STEM ANALYSIS PROGRAM 1979-81

3.1.1 Correlating Site Parameters to Site Class

Warren and Wood (1981) document a number of difficulties in correlating site parameters to site classes. These include high variability in natural systems, a lack of understanding of site/growth relationships, the complexity of site conditions and the complexity of measuring all site parameters that affect productivity. Some factors are too costly to measure and some are unknown. Scientists may be able to explain productivity by site but this does not necessarily mean that sites with similar soil/site properties produce the same volume of wood. Additional factors affect productivity, including the genetic variation of the species.

3.1.2 Results and Observations

General: A set of height-over-age curves and gross-total-volume-over-age curves were produced for each species by site region, site class and soil depth class. Tables listing depth class, site class, and percentage of sample associated with soil texture classes, moisture regimes, position on slope and aspect were prepared. A general comments section was also included on these summary pages (Warren and Wood 1982). Tables listing age, height and gross total volume by 5 year increments and sample number were produced for each species by site region, soil depth and site class. These are filed in binder format.

Warren and Wood (1981) concluded that the assumption that site productivity was greatest in the southern part of the region was valid only for jack pine, red pine, and black spruce on deep soils. They observed that trembling aspen had higher yields in the more northerly site regions 3E and 4E than in the southern site region 5E. They indicated that there were insufficient samples of white pine and white spruce to test the north-south productivity gradient for these species.

The results from their work indicated that shallow and very shallow soils display no north-south progression of yield differences and concluded that factors other than regional climate are limiting growth on these sites. They concluded that regional

climate influences productivity on deep soils more than on shallow and very shallow sites except for trembling aspen.

Position on slope was identified as an important factor correlating to productivity. The toe of slopes supported growth rates that fell into Site Class I; crest positions were frequently associated with lower site classes. Mesic moisture conditions were associated with Site Class I. Wet and dry sites were lower site classes except for jack pine. They suggested that an exclusive, optimal species moisture regime may exist for each soil texture.

Comparison to Plonski's Yield Tables: Warren and Wood (1982) compared the site curves they had developed for the NE Region with those produced by Plonski (1974). They concluded that the curves for jack pine on deep sites were similar to Plonski's site class 1, 2 and 3. On shallow and very shallow sites the jack pine curves were not similar. Warren and Wood (1982) noted that for trembling aspen Plonski's curves were "substantially" higher than the NE Region's site class I and II for all three depth classes. The NE Region site class I curve was 15% below Plonski's curves; the site class II curve was 18% lower than Plonski's (1974) curve. The NE Region's black spruce curves for deep and shallow sites were similar to Plonski's height-over-age curves with the exception of Site Class II in Site Region 4E and Site Class II and III in Site Region 3E which are lower in the early years but similar in the later years. This may be due to early competition. Black spruce curves for very shallow soils do not resemble Plonski's curves, with the exception of Site Class I, Site Region 4E, which is similar to Plonski's Site Class II for black spruce.

3.1.3 Assumptions and Limitations

The 1979-1982 growth and yield project was conducted with the following assumptions. Height-over-age was assumed to be a valid method for dividing trees into site classes because height is relatively independent of density (Spurr and Barnes 1973) within the defined range of density of 500 to 1200 trees/ha. Stand density curves based on limited plot data were assumed to be reasonable approximations of historical stand density. The tree of quadratic mean basal area was assumed to be an acceptable indicator of stand yield for mature stands. Stand density was assumed to vary by species, site region, and site.

Stand density curves for each species are estimated except in the very narrow range of data collected. The estimates are very rough in the younger age classes and the curves should not be used in this range.

Though they pertain to the soils and site where the sample trees are growing, the site descriptions are subjective. Soil moisture assessments are not accurate for the shallow sites as the methods used to assign a relative moisture regime were developed for deep, uniformly textured soils. Soil textures were never verified with lab analysis. Soil and site descriptions focused on a limited number of key mapping parameters, not necessarily on factors influencing tree performance.

Sample trees represent the trees of mean basal area at the time of sampling. No stand history is known. The sample trees were assumed to represent average stand volume at specified ages based on stem analysis. The degree of error in radial increment measurements is not available. Sample sizes are limited for some data sets. No assessment of the differences in site curves for different depth classes is documented.

Many of the aerial photographs that showed plot locations have been misplaced. FRI stand numbers are recorded but the year of the FRI is not. Not all tally sheets were completely filled in.

3.1.4 Recommended Modifications

Warren and Wood (1981) recommended the following modifications for the growth and yield program in the NE Region. The quadratic mean used to select the average tree should be based on all trees greater than 8 cm, not just the principal species. In their opinion, this would provide a better index of stand density. The selection of individual trees should emphasize freedom from defect and irregularities to a greater extent. Height percentages and diameters of the nearest five neighbours should be recorded to better estimate competition and to assess the tree of mean basal area.

A revised method for rating moisture regime for very shallow sites should be developed. Ratings using the standard chart for deep soils appeared erroneous.

More emphasis should be placed on describing the LFH layers, especially on very shallow sites. The texture of the B horizon, and any texture stratifications, should be recorded. Stoniness estimates should be improved and standardized. Position on slope should be recorded with more care to document microtopography. A cross-sectional profile of the plot location should be sketched. Moderately dry and fresh moisture regimes should be further refined because they are frequently transitional classes between two height groups.

SECTION 4: GROWTH AND YIELD REPORTS BY SPECIES AND TOPIC

4.1 WHITE PINE GROWTH AND YIELD CURVE - REGION 4E (4200)

J. Kroetsch (1982) reworked the white pine growth and yield curves for site region 4E (4200). The project was launched in response to the districts' need to determine suitable rotation ages for white pine (particularly in Temagami District) and the Regional Office's need to develop species soil matrices for regional applications, and map forest management potential and forest productivity.

The project's **objective** was to reinterpret the growth and yield data set in terms of soil texture, depth and moisture classes. Each site class curve was to be associated with definable soil types.

4.1.1 Data Base

The original 1979-81 FLaPS stem analysis data set for 69 white pine trees of quadratic mean basal area with trees ranging in age from 80 to 173 years (most between 80 and 120).

4.1.2 Methods

Height-over-age curves were regrouped by height into two classes for site region 4E. Soils and site conditions associated with them were recorded. Two tree volume curves were constructed for each of the two height classes. Volumes of each tree were averaged by 10-year intervals. The resulting curves were so similar that the volumes were regrouped and recalculated to produce one individual-tree volume curve. One mortality (stand density) curve was constructed from the observed stand densities and the stem analysis ages by:

1. averaging observed densities for each 10-year age class (predominantly for age 80 to 120 years, reflecting the data set);

2. selecting 1500 trees/ha at age 20 (estimated from plantation data);

3. selecting 500 trees/ha for ages 140 years and greater as a conservative

value based on stand densities assumed at time of harvest (two measurements of stand densities, 540 trees/ha for age 149 and 580 trees/ha for age 172, indicated that this value was reasonable).

Stand volumes were calculated and plotted for 10-year intervals by multiplying stand density and average individual tree volume.

4.1.3 Results

Stand volume tables for each of two site classes (site class I and II) were calculated by 10-year age class, showing average tree volume (cu m/tree), stand density (trees/ha), stand volume (cu m/ha), stand volume from curve, and mean annual increment (M.A.I., cu m /ha/yr). Periodic annual increment was calculated at a later date and pencilled in on the tables.

Trees on dry sandy loam sites and finer-textured sites often had poorer height growth than stands on coarser-textured sites.

General characteristics of site class I and II are shown below:

Site Class I

coarse sand: shallow, fresh or moderately deep dry to fresh

fine sand: moderately deep dry

coarse loam: very shallow fresh, or shallow fresh or moderately deep dry to fresh

- maximum mean annual increment (MAI) 3.3 cu m/ha/yr
- generally coarse loam and coarser textures, moderately deep or fresh

Site Class II

fine sand: shallow dry

coarse loam: very shallow dry, shallow dry

fine loam: very shallow dry to fresh

- maximum mean annual increment (MAI) 2.6 cu m/ha/yr
- generally very shallow to shallow, dry sites, fine loam and finer soils

4.1.4 Limitations

The mortality curve values were predicted except within the narrow observed range of 80 to 120 years. No permanent stand data was used. Stand densities for older stands were not verified. The weakest part of the volume curve is in the age class 120 year+.

4.2 WHITE PINE GROWTH AND YIELD CURVE - SITE REGION 5E (5200)

A similar project to re-examine and document white pine growth and yield for site region 5E was completed by J. Kroetsch in 1982.

The **objective** of the project was to reanalyse the 1979-81 growth and yield data set focusing on the relationship of height growth patterns to soil texture, depth and moisture. Methods of analysis were to be documented and trees regrouped into site classes associated with these soil parameters if appropriate.

4.2.1 Data Base

Sixty-one trees on 21 plots from the original stem analysis data set (1979-81 were re-examined; 6 were from deep sites (120 cm +), 14 from very shallow sites (5-30 cm) and 41 from shallow sites (30 cm - 120 cm), ranging in age from 60 to 110 years.

4.2.2 Methods

Height-over-age curves were divided into three height classes based on height patterns. Height class was plotted against associated soil and physical features collected for each site. Height classes were grouped into two site classes that could be recognized by similar physical site factors (soil depth, texture, moisture, or aspect). Average tree volume was recorded for 10-year intervals by interpolating from the total tree volume-over-age curve and averaging.

A mortality curve for each site class was constructed from the observed stand densities and stem analysis ages. Observations ranged from 60 to 110 years. Site class I appeared to lose 12 trees per ha per year to a low of 500 trees/ha at age

140 based on the observed data set. The initial density was set at 1680 trees/ha; the rationale was not documented. The mortality rate for site class II was lower at nine trees/ha/year with an initial density established at 1500 trees/ha/yr to a low of 500 trees/ha/yr at age 120 and older.

Stand volume curves were constructed by multiplying the density by the average tree volume, plotting and "smoothing". Height class was ordinated by soil depth, moisture and texture to test the NE Region's FLaPS species selection matrices.

4.2.3 Results

Trees could be classified into two site classes as follows:

height class 1 -- 13.0 m average height at age 50 -- site class 1
height class 2 -- 11.0 m average height at age 50 -- site class 2
height class 3 -- 8.9 m average height at age 50 -- site class 2

Site class I corresponded to sandy loam and courser-textured soils with SE,S,E or level aspects, and one deep site; or very shallow humic layers over bedrock with southerly aspects. Site class II corresponded to loams and finer-textured soils; or very shallow humic layers over bedrock with a northerly aspect.

Stand mortality for site class I ranged from 12 trees/ha/yr to a low of 500 trees/ha. Stand mortality for site class II averaged 9 trees /ha/yr.

The same site classes were generated by ordinating the height classes by soil texture, depth and moisture as above. For the shallow soils site class I is found on sandy loam and courser-textured soils. Site class II on loams and finer-textured soils. Moisture regime assists in differentiating site class II on coarser textured soils since very fresh and moist soils are site class II regardless of texture.

The limited information on very shallow and deep soils conforms to class ordination for shallow soils.

4.2.4 Limitations

Very little data were available for very shallow and deep soils.

4.3 LATCHFORD MANAGEMENT UNIT WHITE PINE GROWTH AND YIELD PROJECT

The **objective** of the Latchford project (carried out by Kloss (undated report)) was to compare stand yields for white pine in the 81-to 100-year age class with yields from the same stands at age 120 within site region 4E (4200). It was triggered by a conflict between OMNR district forest management staff objectives and guidelines for white pine and a forest company's request for harvesting white pine at younger age classes.

4.3.1 Data Base

The NE Region growth and yield stem analysis data set and the FRI provided the data base for this project. The numbers of trees used in the analysis were not documented.

4.3.2 Methods

Kloss prepared an individual tree volume curve, adopted a stand mortality density curve and prepared a stand yield table. He determined average age, average stocking and average white pine content of existing white pine stands in the 81-100 year age class. Then he calculated present yield from those stands and at age 120. Results were presented as differences in yields.

White pine stands in the 81-to 100-yr age class were identified and subdivided into 81-to 90-and 91- to 100-yr age classes. For each age class average (weighted by area) white pine composition, age and stocking were calculated.

4.3.3 Results

Yields at 88 and 98 years for white pine averaged 231 and 272 cu m/ha. Yields multiplied by percent white pine composition, stocking and area identified a present

volume of 183,038 cu m in the Latchford Management Unit. If stands grew to age 120 this study predicted yields of 263,030 cu m based on a normal yield of 355 cu m/ha, an increase of 79,992 cu m. The average delay for obtaining extra wood was identified as 29 yrs.

The average annual increment of stands managed on a 90-year rotation was 2.67 cu m/ha/yr. The volume from the 81- to 100-year age class adjusted to 120 years was 239,630 cu m, thus the volume expected from the same area was 23,400 cu m greater than the adjusted present harvest. Volume would be 10% greater if stands were allowed to grow to 120 years.

4.4 RED PINE GROWTH AND YIELD CURVE - SITE REGION 4E (4200)

Project **objectives** were not documented. The program analysed and reinterpreted the regional red pine (Pr) growth and yield data to assess productivity based on soil texture, moisture and depth.

4.4.1 Data Base

The data base consisted of 115 Pr from 30 plots. Fifteen trees were growing on deep soils (100 cm).

4.4.2 Methods

Initially height-over-age curves were constructed using stem analysis data for each tree. These curves were grouped into seven classes based on similar height growth patterns. Average height at age 50 was calculated and recorded for each of the seven height classes. The height class of each tree was plotted on axes representing physical site features. The factors that consistently distinguished a height class were noted. Height classes were grouped into three site classes based on similarity of associated soils.

4.4.3 Results

The height at age 50 for each height class was:

Ht. Class	Height (m)
1+	17.1
1	15.1
2	11.9
3	11.4
4	8.3
5	8.0
6	4.8

Three site classes were distinguished based on physical site factors and height growth:

Site Class	Height classes and site factors
I	1+, 1, 2 moderately deep, silty sands and coarse or very shallow fine sands MAI=3.9 cu m/ha/yr
II	3, 4 very shallow very fine sands, silt loams, moderately fresh and fresh sites MAI=2.1 cu m/ha/yr
III	5, 6 very shallow very fine sand, silty loam and moderately dry MAI-1.4 cu m/ha/yr

Moisture, position, slope and texture did not clearly separate site classes. Site class II was common on shallow sites (30 -120 cm). On more northerly aspects both site class III and I occurred. Observations on very shallow sites were similar to those on shallow sites. Site class associations with soil texture and moisture for very shallow sites were adopted for shallow sites.

Individual total tree volumes were averaged for each site class to generate average

tree volume. The data were presented in tables.

Stand volumes were calculated by multiplying average individual-tree volumes by stand density. Stand density curves were calculated from the data set assuming 570 trees/ha for ages 120 to 200. The density curve developed for site class III assumed 710 trees/ha for 120 to 200 yrs.

Based on the data sets the following site factors used in the Forest Land Productivity Survey species selection matrices are associated with the corresponding site classes:

Site Class I:	moderately deep (120 - 300 cm), dry and fresh coarse sand, fine sand, and coarse loam shallow soils (30 to 120 cm), dry and fresh coarse sand and fine sand very shallow, dry and fresh coarse sand and fine sand
Site Class II:	shallow (30 cm - 120 cm), fresh, coarse loam to clay very shallow, fresh, coarse loam to clay
Site Class III:	shallow (30 - 120 cm) dry, coarse loam to fine loam very shallow, dry, coarse loam and fine loam

4.4.4 Limitations

No data were collected for moist or wet sites. No data were available for moderately deep fine loams and finer-textured soils. The various tables with data summaries of site conditions by site class contradict each other.

4.5 RED PINE GROWTH AND YIELD CURVE - SITE REGION 5E (5200)

A report was prepared summarizing the growth and yield data for red pine in site region 5E as part of the review of the rotation age for red pine and the development of species soil matrices for the NE Regional forest management potential application.

4.5.1 Data Base

One hundred and two red pines from 31 plots were used for the analysis. Twenty-two of the sampled trees were from very shallow (5 - 30 cm) sites; 30 trees were from deep sites.

4.5.2 Methods

Height-over-age curves were constructed using stem analysis for each tree. These curves were grouped into six height class curves based on curve shape and an average height at 50 years was assigned. For each tree, height class was plotted on axes representing physical site features. Physical site features that consistently distinguished a height class were noted.

4.5.3 Results

The following height classes were distinguished:

Height Class	Height at Age 50
1+	22.0 m
1	15.6 m
2	12.5 m
3	10.2 m
4	9.5 m
5	5.8 m

Three site classes were identified that could be indexed by measured physical site properties:

Site Class	Height Class	
I	1+, 1	Moderately deep and deep soils (120 cm+)
II	2	6 of 7 trees very shallow soils (5-30 cm) very fine sands & coarse sands Shallow, very fine sands and coarser textured soils (80% of samples) 16 of 32 trees on shallow (30-120 cm) finer-textured soils were classified as site class II Northerly aspects and slopes less than 5%
III	3,4,5	Very shallow soils primarily on silty sand and finer-textured soils 16 of 32 trees on finer-textured shallow soils were classified as site class III

Individual tree volumes were averaged for each site class to yield an average tree volume; presented by age in tables. Stand densities for site class I and site class II exceeded those of white pine and red pine in site region 4E. Stand densities for site class III were similar to the general curve produced for white pine and red pine in site region 4E.

The following FLaPS site descriptions were defined for each site class:

I	Deep soils
II	Shallow and very shallow soils, fine sand, coarse sand
III	(later reclassified as IV for mapping) Very shallow sites, coarse loam, fine loam, silt or clay
II-III	(later classified as III for mapping) Shallow sites with coarse loam, fine loam, silt or clay family particle size classes.

4.5.4 Limitations

Limitations of this project were similar to those associated with the reassessment of growth and yield for white pine in site region 4E and 5E and red pine in site region 4E. There are limitations in the definitions of site classes II and III, which corresponded to very different soil- and site conditions.

4.6 YIELD TABLES FOR BLACK SPRUCE GROWING IN SITE REGION 3E

4.6.1 Data Base

R. Collier (1985) developed yield tables for black spruce in site region 3E. The data consisted of 59 black spruce trees from the original 1979-81 data set and seven additional trees collected in 1984 in the course of whole tree jack pine destructive plot sampling. Only four of the samples had reliable soils data.

4.6.2 Methods

A complete discussion of methods on black spruce yield tables is reported by Collier (1985). Height-over-age and volume-age graphs were generated at the same scale for each tree. Graphs were visually sorted into groups of trees that exhibit similar growth patterns. Volume-age data were fit to a modified cumulative Weibull distribution on a tree-by-tree basis. Coefficients of resulting functions are correlated with site factors collected for each tree. Groups of trees with similar growing patterns are described by the site characteristics best related to the coefficients.

The Weibull function was fit to the grouped volume data. The natural logarithm of the number of stems/ha as determined by a field plot count was regressed upon the natural log of the volume of the stems to produce a model to determine the number of stems over time. The coefficient of the group fitted the Weibull function. Thinning curves were used to generate yield tables for each site type.

The -3/2 power law was used to develop a stocking function:

In (number of stems) = K + M (stem volume) - (K and M are regression coefficients)

Coefficients were examined to determine any relationships of site factors to growth. Slope and aspect were the two site factors that had the highest correlation to the Weibull coefficients with a correlation of 40%. The asymptote value 'a' of the Weibull function correlated to height at age 50 at a 50% correlation level.

4.6.3 Results

Yield tables were prepared listing number of stems, tree volume, stand volume, mean annual increment and current annual increment by 5-year increments for four site classes. The associated Weibull curve functions are documented. Site class A occurred on moderately deep soils with impeded drainage, site class B on organics over bedrock on south or west aspects, site class C on NE slopes with impeded drainage, and site class D on shallow rocky soils of sandy loam or soils with high water tables.

4.6.4 Limitations

Limitations of the project included: the stocking curve was based on limited data, there was a high degree of heteroscedacity in the data set which made manual sorting of trees into groups of similar groupings difficult and there was some variation in the groups depending on whether height-over-age or volume-over-age curves were used. In addition there were no data on the degree of decomposition of litter layers which may be related to site classes for black spruce. There was also a limited data set for scatter was evident in the data. No test for even age of the sample stands was conducted. There were limited soil/site data from which to infer any relationships between soil factors and growth and yield.

4.7 COMPLETE PLOT SAMPLING TO EVALUATE TREE OF MEAN BASAL AREA 1985

This project was carried out in jack pine in Hunt Township, site region 3E near

White River.

4.7.1 Purpose

Collier (1985) reports that the purpose of the project was:

1. to evaluate how well the tree of mean basal area represents stand volume, and

2. to estimate variability of tree volumes within a typical plot.

The project tested the assumptions that boreal stands are even-aged, consist of single species, and have trees of uniform height (more or less unaffected by stand density). If these assumptions were correct, stand volume would be equivalent to stand height times basal area and therefore the tree most representative of average volume would be the tree of average basal area.

4.7.2 Methods

A 20 by 25 m plot was located in a jack pine stand (FRI stand 163, Hunt Twp., Site Region 3E). Trembling aspen and black spruce were minor components of the stand. Inferences to sampling for these species were made. Four jack pine trees of mean basal area were identified using standard mensurational techniques. Five 2 by 2 m vegetation plots and two soil pits were located and described in the plot using the standard NE Region tally sheets. All trees were sampled at 1 m intervals for stem analysis.

4.7.3 Analysis

The UNIX/STAT regression package was used to develop local volume tables. These are on file in the NE Regional office (no file number, filing in progress). An equation describing volume as a linear function of DBH (o.b.) and height was derived. No residual analysis was completed to evaluate the validity of the regressions used to produce local volume tables.

The average diameter of the plot, average age, average basal area, and average

tree volume was calculated from data on all species (55 jack pine, black spruce and three trembling aspen).

4.7.4 Results

Mean stand age was 53.36 years with a standard deviation of 2.72 and a standard error of 0.33 years. Average age of jack pine was 53.67 yrs with a standard deviation of 1.91 and a standard error of 0.26 yrs (there is an 8-year range for jack pine in the plot). Plot skewness was -0.29 for plot and -0.72 for jack pine alone. Plot kurtosis was 3.88 for the full plot and 2.96 for jack pine age structure. Spruce was slowly invading the understory; jack pine was crowding out aspen.

The even-aged stand assumption is valid for jack pine stands in boreal forest. It is not completely valid in mixed stands.

Local density was determined for each tree using Hiley's intertree spacing factor. Increments were measured on a digitizer (TRIM system) and data entered on the DEC PRO-350. Tree volume was calculated in cubic decimetres; tree basal area calculated in square centimetres.

Diameter/Basal Area Evaluation

The average diameter at breast height, outside bark (dbhob) for the jack pine component was 17.8 cm with a range of 14.1 cm, a standard deviation of 3.49 and a standard error (S.E.) of the mean of 0.47. The coefficient of skewness was 0.04 for jack pine and -0.16 for the plot. The coefficient of kurtosis of 2.15 for the jack pine component increased to 2.46 for the plot. If all species on the plot are included the average diameter decreases to 17.21 cm, the range increases to 16.8 cm, the standard deviation increases to 3.88 cm and the standard error of the mean increases to 0.48. These changes are largely due to the black spruce component.

The average plot basal area (B.A.) was 243.67 sq cm. The average basal area for the jack pine component was 569.56 sq cm corresponding to a tree of 18.17 dbh. The average aged tree had a dbh of 17.87 cm. Greater weight was given to larger trees. Using the midpoint of diameter classes instead of actual diameters to

calculate the dbh of the tree of mean basal area assumes a random effect. The use of the frequency table yielded a higher value of dbh of 18.55 cm.

Volume

Plot volume was 12,192.95 cu dm equivalent to 243.8 cu m/ha. This consisted of 11,980.21 cu dm of jack pine, 629.07 cu dm of aspen and 474.67 cu dm of black spruce. The average plot jack pine volume is 201.62 cu dm. Tree number 64 was both the tree of average basal area and the tree of average volume. The tree of average basal area did represent the volume of the stand based on this limited sample.

Individual Tree Height and Volume Growth

Average tree height was 17.2 m with a range of 13.2 m. The average height of jack pine was 18 m with a range of 8.3 m. Four trees of average height for jack pine did not represent trees of average volume. The variance of volume estimates of jack pine was 8,885.9 cu m at the time of the cut.

Black spruce growth was similar to tree growth of average basal area from other stands in site region 4E. Collier (1985) concluded that stand history, and specifically competition, may have a greater effect on growth than soils.

4.7.5 Limitations

Collier (1982) identified a number of limitations in the approach and data set he used for the project. He identified the absence of a mechanism for accounting for the volume of rot in trembling aspen, and the absence of a measure of variability of mean volume for the stand within the standard FLaPS growth and yield procedures. In addition he noted that the mean volume of target species does not necessarily represent mean stand volume if stand composition is mixed. He noted that there was no reliable measure of stand history or competition over time. The tree data were taken from stands where the even-aged assumption was not validated before the tree of mean basal area was sampled to represent stand volume.

Collier notes that the stand density curve was fabricated. He pointed out the

presence of a good growth model based on individual tree growth but a weak stocking model for developing the yield functions on an area basis.

4.8 WHITE BIRCH STEM ANALYSIS PROJECT

Ms. Lauren Quist, a contract project forester for the NE Region, carried out white birch stem analysis in 1983-84. The project was implemented in response to questions of how to manage sapling white birch stands and how to identify sites for sawlog production. A study was initiated to determine "what individual tree volumes and yields could be expected from which sites" and "how should stand density be managed" (Quist 1984).

To determine the existing range of white birch site classes based on Plonski's yield curves and to assess the quality of birch across the region, the NE Region was searched for stands eligible for stem analysis. Suitable stands were grouped by site class. Preliminary information on the relationships between tree growth and origin, stand density, topography and soils was obtained. Hypotheses about relationships between these variables were to be tested by analyses of stands, stems and soils.

The **objectives** of the project were (Quist 1984, p. 2):

- to assign a site class rating for a given physical site using height growth as an indicator;

- to produce productivity curves for given forest sites;

- to determine how the merchantability of individual trees can be maximized (ie. the effects of spacing on diameter growth and forking);

- to test the hypothesis that white birch growth was better in the transition zone than in the hardwood and boreal forest zones;

- to sample 16 plots across the region.

4.8.1 Methods

Stands were selected that were over 50 years of age, with over 50 percent white birch by basal area, over 70 percent stocked by Plonski's standard (over 400 white birch trees/ha), mostly free of butt rot, on Crown land, but not in parks, within 600m of a road, and not within 15 km of the Great Lakes (to minimize lake moderating effects). To test the hypothesis about good growth in the transition zone, samples were concentrated along the site region 4E/5E transition. The literature indicated that birch grows best on deep, loamy soils. Soil maps were overlaid with FRI maps to find mature birch stands on fresh medium to deep soils of fine sand to clay. This approach was abandoned as very few birch stands met with criteria. Stands were located by consultation with unit foresters and by using FRI maps. Stand ages were younger than the FRI indicated and the white birch composition was lower. Mature stands often contained over 50 percent second growth of other species.

The site index procedure of the Forest Soils Survey Reference Manual (1983) was used in eligible stands. One to three plots were established 40 m apart. At each plot, two trees were selected. Height, age, dbh, distance to five closest neighbours, seed origin versus sprout origin, form defects and basal area by prism sweep were recorded. One soil pit was excavated and described for each plot. Seventeen site class X to 3 plots ranging from 50 to 100 years of age were located across the region with great difficulty. Most stands had observable rot, or did not meet the composition or age requirements. The reconnaissance plots became the sample for stem analysis.

Only 14 plots were sampled. One plot was considered too close to other plots. Two in Wawa District were rejected due to crown dieback. Six plots from a separate study in Wawa were incorporated into the data set. The Wawa study sampled two trees with dbh greater than the mean and two trees with dbh lower than the mean.

Plot distribution included plots in North Bay (4E, 5E), Sudbury (4E), Espanola (4E and 5E), Blind River (4E and 5E), and Wawa (3E). The additional plots from the earlier Wawa District study included plots in 4E and 3E. A list of townships and stand numbers is included in Quist (1984, after p.4) and plot locations are mapped

(Quist 1984, Appendix 4).

Plots were described following the NE Region's stem analysis procedures (Forest Soils Survey Manual 1983) with a few additions including the recording of seed versus sprout origin, defects affecting veneer status, rot, fork height and percent volume of branches compared to main stem above fork volume. The Wawa study did not include any of these extras except for fork height and percent branch volume.

Soils were described for a 60 cm deep pit rather than a 1 m deep pit as per specifications. Pits were shallower if excessive cobbles were present. Soils, with the exception of sands, were collected for laboratory analysis. Textures were in the correct family particle size class compared to laboratory textures in 64% of the samples checked, with a bias towards underestimating the proportion of fine particles. Special care was taken to note the location of the tree on the slope to determine if it was located on a receiving or dispensing micro-site.

Discs were removed at 1 m intervals from the four trees closest to the quadratic mean basal area. Disc shrinkage was minimal. The error in aging was 4% in 95% of cases or 4 yrs per 100 years. This estimate was based on duplicate measurements of several discs by four different staff members. Discs were measured with a digitizer attached to a Radio Shack microcomputer. Increments were read in one year intervals along mean radii. A program was developed to calculate gross merchantable volumes including branch volume.

Soils were grouped into three types based on family particle size as follows:

1. tills: fine loams (silt loams, loams) few to moderate stones, cobbles -- 7 of 17 plots;

2. tills: coarse loams (silty sands, loamy very fine sands), few to excessive stones/cobbles -- 5 of 17 plots;

3. glaciofluvial sands: fine sands (fine sands, silty medium sands, loamy fine sands) stonefree -- 5 of 17 plots.

Soils and site data for three of the Wawa plots were not available. Soil moisture regime was based on soil texture and therefore was not treated as a separate factor. All surface organic horizons were classified as "mor" 3-8 cm thick; this was not used in the analysis. Soils were described following the 1984 FLaP soil survey procedures.

Ground vegetation was fairly consistent, with Clintonia, sarsasparilla, mountain maple, beaked hazel and largeleaf aster occurring in almost all stands. Shrubs and balsam fir regeneration occurred in all plots (Quist 1984).

Height classes

It was assumed that height is controlled mainly by site quality independent of stand density and thus is the best indicator of site quality. Individual-tree height-over-age curves were grouped into 11 classes. Tree height curve classes were grouped into 5 site types based on similarities of curve, soil texture, topography, stand density, species composition and seed-versus sprout origin. Height class differences associated with differences in each site factor were quantified by comparing classes of trees on plots where all site factors except one were similar.

Rating site factors

The different values of site region, soil texture, percent slope and stoniness were assigned ratings. For example, site region 5E was assigned four points, 4E-3 (site district 3) three points and 4E-4 two points. Site Region 3E was assigned one point. Stand density was subjectively assigned a value based on the degree to which that factor was correlated to positive height growth. The points were totalled and a rating assigned to each tree. A table was constructed identifying the height type and yield class. This process is outlined in Quist's (1984) file report.

Two well-stocked stands in South Lorrain Twp in Temagami District were measured for site index. The soils were lacustrine deposits of silty clay loam. Trees were ranked as height type 1 to 1++ compared to Quist's (1984) stem analysis data set. Seven stands in Bastedo Twp, North Bay District, were measured for site index by another crew. All trees were ranked as height types 1 to 1+++ compared to Quist's

study. Soils ranged from medium sand to silty loams and from deep to shallow. Those trees growing on silt loam were one class taller than trees growing on very fine sand.

Diameter growth

Height and diameter of adjacent trees of equal age and origin subject to different spacing were compared based on the site index data. Curves of diameter at breast height (inside bark) over age were grouped into dbh classes. One tree per plot was graphed.

Total Stand Volume, Stand Density and Yield Curves

Total stand volume per hectare was determined by calculating volume of birch and volume of other species from OPC tables. For birch, heights were estimated from a curve of plot height over diameter developed from the data from the five nearest trees. Other species heights were estimated from the birch's relative position in the table. Estimates of branch volume were made from stands where no branch estimates had been made in the field by using 70% of main stem volume above fork (gross total volume minus gross merchantable volume minus stump volume). This was added to gross total volume. Branch volume was generally under 10% of gross total volume.

Stand density was expressed based on number of stems in the plot translated into stems per hectare. The number of stems of other species present in the plot was converted to the equivalent number of birch of average birch volume. The spacing around each sample tree was used to express stand density to correlate to individual tree data.

Yield curves were calculated for each plot by multiplying the gross total volume of the average sample tree at 5-year intervals by the number of trees per hectare for that age from the high or low stand density curve. The low curve was used for type 1 tree plots; the high curve for the remainder with two exceptions. The high curve was applied to type 1 plots with low diameter classes and high density (as initial high density assumed); the low curve was applied to five type 2 plots with

high diameter classes and low density.

Merchantability

The minimum dimension of a merchantable sawlog was defined as 22 cm diameter outside bark (dob) at 3.3 m. Dbh classes were estimated from known age, dbh and/or stand density.

Gross merchantable volume was calculated with a locally developed computer program. Volume to fork height was used to determine some branch volumes. Defects and rot in sample trees was noted. Several mean basal area trees were bored at stump to check for rot before selected as sample trees. Presence of crown dieback and rot was recorded for individual trees, as well as their origin (sprout versus seed) to subjectively assess any correlation.

4.8.2 Results

Soils

All plots were well-drained, moderately deep to deep soils (60 cm +) with no root-impeding layer. Textures were in the correct family particle size class compared to laboratory textures in 64% of samples checked with a bias towards underestimating fine particle content.

Height Class

Differences of one height class were found between the following situations:

1) Hills's site region 5E, site district 1 supported more merchantable volume than site region 4E, site district 3. Site region 4E-3 supported more merchantable volume than site region 4E, site district 4 which in turn supported more merchantable volume than site region 3E. This supported the hypothesis that white birch was more productive in the southern part of the region. More dieback was recorded for trees growing in Site Region 3E. Interpretation of results should take this into consideration. The causes of the dieback have not been confirmed.

2) Higher productivity was observed on silt loam and loam soils than on silty sands and loamy very fine sands. Sandy soils were the least productive. Textures referred to the control texture which defined the moisture regime. Moister soils appeared to support better growth.

3) Merchantable volumes were higher for trees growing on deep soils (1 m+) than on shallower soils. Caution should be exercised in applying this relationship as very few trees were sampled from moderately deep and shallow soils.

4) White birch growing in toe positions reached merchantable volumes at earlier ages than those growing on midslope or crest positions. Quist based this conclusion on the trees in one plot.

5) Greater tree growth was observed on sites with no or few gravels and stones, moderate growth on sites with few to moderate stones and poor growth on sites with moderate stones and moderate cobbles. Poorest growth was observed on sites with excessive stones and cobbles. This may reflect a decrease in rooting soil volume on stony sites or it may be related to the occurrence of stonier sites on steep slopes.

6) Quist did not identify any correlation to aspect.

Diameter Growth

Type I trees had rapid and steady growth. Type 2 trees had fast initial diameter growth which abruptly slowed, reaching lower total heights less than type 1 and 1+ trees. Type 3 trees displayed slow steady growth but eventually reached similar diameters as class 1 trees. Type 4 and 5 trees never displayed good diameter growth. Type 4 curves of diameter over age were nearly linear. Trees on sand were classified into one diameter class greater than their height type. These trees were short and thick. Trees growing on loam soils were ranked into height classes greater than their diameter class. This may reflect soil texture and stand density. Quist (1984) noted that stand density was lower on sandy soils.

Trees growing in denser stands were grouped into a lower diameter class.

Between plots of equal density for age there was no consistent correlation of soil texture to diameter.

Volume, Stand Density and Yield

The data collected on gross total volume (GTV) over age for each tree did not level off. No peak volumes could therefore be estimated based on this data set. Volume growth was similar between trees of similar diameter within the same plot. No correlation of total volume per hectare with site characteristics was identified from the data by Quist (1984). There was a consistent, observable increase in total volume with age for trees growing on sandy soils. This was not apparent in trees growing on loamy soils. Diameter growth had a greater influence on volume than height for trees growing on sandy soils.

Plot density and density based on individual tree spacing (to nearest neighbours) varied greatly. This reflects the methods used. Only canopy trees were counted as nearest neighbours, thus reducing the density estimate. Sprout trees in clumps had higher nearest-tree density values than seed trees growing in plots of equal plot densities. The graph of plot average densities versus age had a wide scatter. To tighten the scatter "normal" plot average densities were estimated by calculating an average stand density index (SDI) of all plots as

$$\log J = -1.314 \log dbh + 4.64, \quad \text{where the SDI} = 2124.4$$

A strong correlation of $r^2 = -0.81$ indicated that average dbh depends more on population size than on age. Plot average diameter was used in the SDI equation to obtain a "normal N". Type 1 plots had lower densities so two curves were drawn. To extrapolate beyond the range of data, curves from Plonski's 1960 data were followed to age 20 and estimated. The curves fell above Plonski's (1960) white birch site class 1. The lower density on higher type plots resembled the pattern of Plonski's curves. Low height growth may be caused by initial overcrowding or by poor site quality resulting in low height growth and overcrowding.

There was no consistent relationship between stand origin and density. Type 1 trees on high density plots had a low dbh class. Type 2-5 trees on low density

plots had a high dbh class (thus high yield or high initial dbh growth (dbh class 2d). Quist (1984) provides a discussion of these observations.

High type 1 gross total volume curves were multiplied by the lower density curve. Type 1 plots had consistently higher yields over time than types 2 to 4. Type 3 plots had high initial yields that abruptly slowed. Type 5 yields were lower. At age 80 all curves increased linearly, with few exceptions. There was a rapid increase of individual gross total volume and slow decline of stand density at age 80.

Predicting Yield

Quist (1984, p. 14-15) produced a key for estimating yield. Site factors were described and rated. Refer to Quist for a discussion of class ratings.

Merchantability

- dbh class 1+ trees reach 22 cm dbh by age 60;

- class 2 and 3 trees reach 22 cm dbh by age 90;

- class 5 trees reach 22 cm dbh by age 100 (but many trees have butt rot);

- some class 2d,2,4,4d trees never reach merchantable size.

Volume Loss to Forking

Branch volume was 1 to 10% of the gross total volume. In all but six of 44 trees there was no clear trend of increasing branch volume with increased inter-tree spacing. Fork height was low on the more widely spaced trees in 8 of 11 plots. No forks were recorded in first 3 m log. Sprouted trees had sweep slightly more often than seed-origin trees on one plot as expected. Sweep occurred more often on rocky hillsides than on flat ground. Rot increased directly with stand age. There was no correlation with soil type. Most trees in Wawa District displayed dieback with up to 3 m of dead tip.

4.8.3 Conclusions and Limitations

Highest gross total yield were observed on sites of a given quality by stands with the lowest density for their age. Trees in these stands also have the highest individual GTV over age. Site class, stand density and stand yields did not correlate with sprout- or seed origin. All but three plots exceed minimum density for full stocking (Solomon and Leak 1969).

Plot density and density based on individual tree spacing (nearest neighbours) varied greatly. Only canopy trees were counted as the nearest neighbours which reduced this density estimate. Sprout trees in clumps had higher nearest-tree density values than seed trees growing in stands of equal overall plot density. No understocked stands were represented in the sample, yet conclusions about stocking were made.

Reconnaissance data from the Wawa study revealed height differences up to 2m, yet these trees were integrated into the basic data set.

Sample stands were selected using restrictive sampling criteria which resulted in a concentration of stands in the Peshu Lake Unit of Blind River District, and the Wawa and Jack Pine crown management units, Wawa District. Of seven stands east of Blind River only one was more than 71 years old. Stands with rot were not selected, which biased the sample. Stands below age 60 were used although they do not show trends past age 80. Most sprout stands are still under age 60, but they were selected and growth trends beyond this age predicted. Some site factor combinations were not represented. For example, all site region 4E plots were located on tills except one. Total sample numbers were limited.

Estimates of branch volume were made for stands where no field branch estimates had been recorded by using the average value of 70% of main stem volume above fork (GTV minus GMV minus stump volume). Actual measurements varied from 30 to 100%. Branch volume was generally under 10% of gross total volume.

4.9 NORTH BAY HARDWOOD GROWTH AND YIELD STUDY

Procedures and preliminary results of the North Bay hardwood growth and yield study are summarized in a report by Heaman (1984). As indicated in the terms of reference for this summary of the FLaPS program, a summary of the hardwood project would be beyond the scope of this report.

4.10 REVIEW OF FLaPS GROWTH AND YIELD PROCEDURES

Niemi and Collier (1984) recommended changes to FLaPS upon a request by the regional ecologist.

The purpose of these recommendations was to:

- reduce the complexity of the task of producing yield tables,

- increase the accuracy of yield tables produced from the survey data, and

- increase the usefulness of the data base for other purposes.

4.10.1 Methods of Review

The NE region growth and yield sampling procedures were applied (FLaPS 1984 manual). Intertree distances and direction (azimuth) of the 20 living trees of the species of interest closest to the tree of average basal area were determined. In addition, a circular subplot centered on the tree of average basal area was established, with a radius equal to the distance between the tree of average basal area and the 20th tree of the same species. In this subplot, the distances and azimuth were recorded from the centre to all trees of other species with a dbh greater than 8 cm and dead trees. The tree of average basal area and the ten closest living trees of the species of interest were felled and sectioned. Crown class, number of leaders and health of the tree were recorded.

In addition to the standard soil pit excavated at the base of the tree of average basal area, soil pits were dug at the base of one cut tree from each remaining crown class. Each pit was marked on a scale diagram of the plot. Five 2 m by

2 m ground vegetation plots were located in a cross shape with plot 1 close to tree of average basal area. Remaining plots are located halfway between tree of average basal area and a subplot at each cardinal direction.

4.10.2 Disadvantages and Limitations

Field work costs are greater for this modified sampling approach. Sampling is slower. A three-person crew can complete one prelocated plot per day. In contrast a two-person crew could complete two plots per day using the basic sampling procedures. There are increased costs for disc measurement with 2 additional days required for data entry and verification per plot. The basic procedures require 1.5 days for disc preparation and data entry with 1 additional day for checking per plot.

There may be sufficient vegetation plots for statistically valid interpretation of plant-soil relationships along two gradients.

4.10.3 Advantages

Analysis would be easier using the modified data collection system. The data are more reliable. Area and thus density are built into the model, which eliminates the problem of extrapolating from a single tree to an area basis with reasonable accuracy. There would be reduced sampling for other information in related studies, for example quantifying the effect of competition on individual tree growth. It would provide data on dominant trees, facilitating the production of site index curves. It establishes permanent sample plots of ten trees for use in later studies.

4.11 SUGGESTED SAMPLING PROCEDURE FOR COPPICE ORIGIN STANDS WITHIN THE FLaPS PROGRAM (based on discussions with G. Murchison and W. Carmean, Faculty of Forestry, Lakehead University, Jan. 1985)

G. Murchison recommended that plot shape be changed to a circle with a radius of 12.62 m to reduce plot establishment time. He also recommended that Hiley's inter-tree spacing factor be replaced with the polygon method of calculating area of a polygon formed by neighbouring trees of the species of interest. Surveyors should record diameter, height, age, distance and compass direction of all trees which influence the tree of interest. Hiley's inter-tree spacing factor assumes a

uniform distribution of stems and gives acceptable results only if trees are uniformly distributed.

For coppice-origin trees Carmean and Murchison recommend using the standard mensurational practice of considering trees that fork below 1.3 m as two trees.

4.12 FLaPS GROWTH AND YIELD PROCEDURES - A CRITIQUE BY COLLIER (1985)

4.12.1 Terms of Reference

Collier (1985) indicated that FLaPS Growth and Yield program objectives are not clearly defined. Is the purpose to develop yield tables or curves or both? To what degree of accuracy are the yield tables to be produced? For example is the required accuracy plus or minus 10% of predicted yield at rotation with a probability of error of 5% or less? This would allow one to evaluate whether the sample size was adequate. Standard growth and yield procedures adopted a blanket approach to site sampling. Collier identified the need to review the autecology of each species to be sampled. Each field crew member should be trained in autecology to describe critical site characteristics. Sampling designs should emphasize sampling of the site factors most critical to the growth of the particular species.

Collier also pointed out a lack of computing resources, lack of space for data storage, and lack of analytical software as major limitations in developing applications with the growth and yield data. High personnel turnover with an associated lack of comprehensive documentation of data analysis, data storage format and location of field data and processed data caused discontinuity and inefficiency in the program.

4.12.2 Sampling and Analysis

Collier noted that yield tables were most useful on an area basis and therefore a reliable measure of density (number of stems per hectare) is required. The number of stems per hectare decreased over time. One way to estimate density over time is to extensively sample over a range of stand ages and then to select an empirical function to calculate the number of stems. An alternative is to use permanent

sample plot data to derive a relationship for density. Care must be taken to ensure that any density formula applies to a variety of growth patterns including clumping in white birch, scattered jack pine on rock ridges and uniformly spaced stands on deep uniform sands.

Collier (1985) recommends that full plots be destructively sampled for even-aged stands providing a yield factor on a per-area basis for mature stands. This provides yield information on mature stands. He recommends that as a measure of spacing in even-aged stands stem analysis with distance and direction to neighbours that limit crown space and that polygon area method should be used as a measure of spacing for uneven-aged stands. He identifies the need to combine stem analysis data with permanent sample plot data. He recommends that data from the permanent sample plots be used to derive a thinning model. Data from stem analysis could be used to derive initial estimates of stem volume growth.

4.13 PROCEDURE FOR DETERMINING TREES/HA OVER TIME FLaPS NE REGION

4.13.1 Assumptions

The procedures for determining stand density over time recommended by Collier (1985) assume that there are no overstocked sites and no understocked natural stands unless a fire, epidemic, cutting, windstorm or similar catastrophe influenced the stand. They also assume that the -3/2 power law holds for forest tree species (Harper 1977). This law implied that if the log of mean plant weight is plotted against the log of plant density the resulting line has a slope of -1.5 or -3/2. If mean stem volume of forest trees is substituted for weight, the line has a slope of -1.72 and -1.82. This linear trend applied to Plonski's data, although the line is steeper. The procedures assume that the -3/2 power law defines the rate of mortality with respect to the size of survivors. The data show that although the slopes of the relationship remain the same, the intercepts change with site quality.

4.13.2 Recommended Procedure

Define site types and generate a mean tree growth model for each type. Determine a volume-spacing function for each site type. Determine spacing from

the growth model and produce tables.

4.14 REINTERPRETATION OF JACK PINE DATA FOR SITE REGION 5E 1988

A comparison of the differences between Warren and Wood's (1982) linear regression and the one generated was completed by C. Leale (July 21, 1988 file notes filed under adjusted tables). Significant differences were documented in file notes.

The equations were:

1981 Amik Linear regression: $y = -4.33x + 113.26$ and
1988 S.A.S. regression: $y = -1.9322x + 904.34$.

Warren and Wood's analysis in 1981 used six fewer points for the regression analysis than the 1988 S.A.S. analysis. Three of the densities not used in 1981 are below the AMIK regression line. The other three are marginally above the AMIK regression line at older ages which would explain why the SAS regression line has a flatter slope.

Warren and Wood's density figures in 1981 started at age 20 = 2020 trees, age 30 = 1660 etc. with no rationale for this high figure. The 1988 data analysis used a starting point of age 20 = 1500 trees based on a recommendation of the regional silviculturalist. The remainder of the density curve followed the SAS regression line as closely as feasible. The program for jack pine 5E is D:USR/CHRIS/LP/PR4/PJ5.den.

SECTION 5: TOOLS AND APPLICATIONS

5.1 DEVELOPMENT OF FOREST SOIL GROWTH INDICATOR MATRICES

5.1.1 Objective

The objectives of the Forest Soil matrices and Species Selection Matrices were to:

- provide a 'yardstick' for comparing relative productivity of different species on selected soil types (combinations of soil texture, depth and moisture classes stratified by site region and three broad depth classes)

- facilitate the mapping of relative forest productivity across the region using the FLaPS data set (to be mapped at a scale of 1:506,000) and

- to form the framework for soil and growth and yield applications.

5.1.2 Growth Indicator Matrices

Soil and site factors were listed for each sampled tree (Kroetsch 1982; tables on file, NE Region). Associated height class and site class were listed adjacent to each record. Soil depths were recorded by depth class (very shallow 5-30 cm), shallow (30-100 cm) and deep (>100 cm). Texture was recorded as indicated on the field tally sheet. This was later classified by family particle texture class (coarse sand; fine sand; coarse loam; fine loam on silt; and clay). Moisture regime was recorded as indicated on field tally sheets, together with the modifier, eg. moderately fresh. This was later combined into four moisture classes (dry, fresh, moist, and wet). It is based on the original soil moisture regime chart for deep soils. Moisture regimes on shallow sites were changed by the contractors at their discretion. No records of modifications were made. A summary of the site class most commonly associated with each soil type (depth, moisture/texture class) was recorded for each species by site region.

The maximum mean annual increment (mai) in cu m/ha/year for each site class was

extracted from the 'stand volume' tables for each site region prepared by AMIK in 1982. It is based on average gross total income. Interpretations of appropriate site class for unsampled soil types was completed through discussions with the regional silviculturalist and regional ecologist; the associated maximum mean annual increment for that site class was assigned by species. Data that are based on interpolation and 'best guess' are identified as such in italics on the tables (Kershaw 1988).

5.1.3 Species Selection Matrices

Species selection matrices were prepared from the data set referred to in section 6.1.2. All unit foresters in the Northeastern Region indicated a species preference for each soil type. The species that foresters most commonly indicated as the species they would manage for on each soil type was selected for the table. The associated site class, maximum mean annual increment and rotation age were assigned, based on the original FLaPS growth and yield data set.

The assignment of the rotation ages was based both on the biological rotation suggested by the FLaPS growth and yield data and the discretion of the regional silviculturalist. A 10-year decrease in rotation age was considered to account for the differences in yield between plantations and natural stands. Species indicated for management for which there were no regional data were excluded. Tables were separated into glacio-fluvial/lacustrine and till data sets to account for differences in species selection on level areas assumed to be frost-prone, and more variable till sites assumed to be less frost-prone. Existing forest conditions were not accounted for in the selection of species indicators. The resulting tables are presented in Kershaw's "NE Region, Volume 1, Forest Site Evaluation Field Manual 1988" and rough calculations are on file. It should be noted that several versions of the species selection matrices are on file.

Limitations

There is no documentation of the reliability of the growth- and the soil information. Re-interpreted soils data from the 1984 audit were not integrated in the matrices. No modifications were made to the data set based on the modified soil moisture regime charts. No qualifier is documented concerning the scale of suitable

application of the data. The data set was designed for broad regional application. The origin of this data set is not documented. Sample numbers are not included. The number of entries in the species selection matrices which are based on data are limited. For example, for site region 5200 fourteen of 39 entries or 35 percent of the red pine entries are based on observations. Twenty percent of white pine, 33 percent of jack pine, 26 percent of black spruce, 31 percent of white spruce, and 38 percent of poplar entries are based on observations. The remainder were interpreted site class levels. This provides a good first approximation, but verification and refinement would be desirable for district applications.

The matrices show single values with no reference to the associated yield curves. No age is assigned to the maximum mean annual increment. Information for the hard maple and yellow birch data set is weak. A limited number of species are included.

Variable stocking, mixed stands and plantations are not accounted for. No statement of appropriate applications are identified on the matrices.

Recommendations

The forest soil products are inappropriate for use at the District or Forest Management Unit level without refinement or verification. The existing data set should be summarized by sample number and by revised soil parameters. The degree of reliability of the data set by site region, species, site class and soil type should be assessed. Common site conditions where major species are being or may be managed in the next decade should be summarized. The existing data set should be grouped by these conditions and data needs identified.

Some information is available from the lake states on other species. Consideration should be given to integrating this information.

The rationale for values assigned to interpreted data should be documented. Plantation data where available should be reviewed to determine the relationship to natural curves. The assumption that plantation yields will be similar to natural stands but rotation ages will be reduced by 10 years should be examined. This premise is currently built into the assignment of rotation ages for each site class.

The original data set used to construct forest soil growth indicator tables and species selection matrices included some plantation data. If the species selection matrices and forest growth indicators are to be re-evaluated or applied, this portion of the data set should be excluded. They have been excluded for the development of current (1988) yield curves.

There are inconsistencies in the current version of the species selection matrices. Three inconsistencies between the forest growth indicator tables and the species selection matrices are evident. Till Site Region 3200: very shallow, dry, fine loam, Pj: site class IV or III? Shallow, fresh course loam: site class I or II Pj? Site region 5200, shallow lacustrine, fresh fine sand: site class III or II Pr? These should be made consistent.

5.2 PRODMAPS

A computer matching algorithm was prepared by the regional
forest systems officer which draws on the species selection matrix to match soil types from the regional terrain inventory with a species growth indicator and associated site class and maximum mean annual increment. Computer printouts from the program were used to prepare a set of 1:100,000 scale mylar maps of forest productivity referred to as **PRODMAPS**.

The basic mapping units are the FLaPS terrain units. Each unit is assigned a site class, species indicator and the percentage of the area occupied by each soil type component. For example FLaPS terrain/soil unit #44 is given an associated **PRODMAP** label of IPj 7, II Sb 2 NP 1. Organic and rock components of each terrain (soil) unit are designated 'NP' or non-productive. White pine, jack pine, red pine, white spruce, black spruce, and poplar were included in the mapping program; hardwoods were excluded. The 1988 Forest Site Evaluation Manual provides an explanation of map production and legends.

The fact that hard maple and yellow birch were ignored in the original productivity maps (PRODMAPS) and original matrices, caused some concerns. In response to this concern, interpretations of mai for these hardwoods were made using data from Plonski's yield tables. Three site classes were established and applied to site region 5200. These are integrated into the current species selection matrices, but

not into the PRODMAPS.

5.3 FOMAP MATRIX

5.3.1 Objectives

The forest management potential matrix was developed in order to prepare a map of the region showing the distribution of areas that are 'good', 'intermediate' and 'poor' in terms of suitability for forest management. It was also developed to evaluate forest management potential in terms of forest growth potential and ease of operations based on the land base.

5.3.2 Methods

The properties (classes) of each surveyed soil and site factor (texture, etc.) were ranked on a scale from 0 to 10 as to degree of difficulty it poses to harvesting and silvicultural activity where 0 represented no impediment to management and 10 indicated a physically unmanageable condition. The overall ease of management rating for a given soil type was calculated by averaging the degree of the two most limiting site factors. This could be assigned on site (in the field), to a map unit, or to a reference data set.

A forest management potential rating assigns one of four levels of management (elite, intensive, basic and extensive) to a given set of soil and site conditions based on its combination of productivity rating (growth potential) and ease-of-management rating (Kershaw 1988, p. 14).

5.3.3 Limitations

A forest productivity indicator does not account for differences in local site factors. For example it does not account for aspect, position on slope, proximity to a water body, or historical factors such as stand development. The FOMAP matrix is appropriate only for application at the regional scale in its current form. The intent was to modify the matrix for use at each District level. The FOMAP matrix is biased towards evaluating the ease of management for artificially regenerated species. It is weak in assessing ease of management for natural regeneration. It

does not take into account the current forest cover in an area, access or markets.

5.4 1:250,000 AND 1:500,000 SCALE FOMAP OF THE REGION

5.4.1 Methods

A computer algorithm was written to separate the FLaPS terrain unit code into soil types. This assigns an area percentage and a class of texture, depth, moisture, stoniness, and topography to each component of the map code and a corresponding percentage. This was necessary because the original tally sheets for the units had not been retained after the completion of map ledgers and maps. The compound code on each terrain unit did not clearly indicate which factors occurred together; for example whether a fresh moisture class was associated with the glaciofluvial fine sands or with the shallow coarse loamy till component of the map code.

A field survey testing and calibrating the results of the soil-matching algorithm was conducted as part of the TOMIKO PriSMa pilot. Most of the recommended modifications based on the field survey were never integrated into the model.

Initially the class of stoniness and topography assigned to each soil type within a map unit (FLaPS terrain inventory) was an average value for the map unit. The original forest management potential map (FOMAP) was based on assigning a level of management using this average figure. The FOMAP algorithm was rewritten by the regional systems officer to refine this approach. Each soil type within a map unit is currently assigned its own unique stoniness and topographic class. The matching algorithms were developed based on expert models.

A forest productivity rating from the species selection matrices was assigned to each soil type in each FLaPS terrain unit to reflect growth potential. The productivity of each soil unit was indicated by the weighted average of site-specific maximum mean annual increments for the species most likely to be managed on each soil type.

All mapped soil units across the region were analyzed using these criteria. An optimum intensity of management was assigned based on the FOMAP matrix.

5.4.2 Limitations

The regional FOMAP does not include hard maple, yellow birch, white birch and other less commonly managed species. It considers only red pine, jack pine, white pine, black spruce, white spruce, and poplar. The regional FOMAP map does not reflect the refinement of assigning a unique stoniness- and topographic class to each soil type, though the data permit this refinement.

5.4.3 Recommendations

This author does not recommend using the existing Forest Management Potential map for the region. If the map is needed it should be redrafted using the refined data base now available and hardwoods should be included in the assessment. Units should be mapped by individual FOMAP component rather than by one average value.

Consideration should be given to mapping only the dominant FOMAP rating for units where one rating reflects 70% or more of the unit. Revised mapping criteria should be developed. If FOMAP is to be used on a district scale, the FOMAP matrix should be refined to reflect the target management unit and the range of conditions and management opportunities and limitations for the area. The rationale for any modifications to the regional matrix should be documented. The species productivity indicator matrix should also be refined to reflect the conditions in the district. Prior to the application of the FOMAP, a test of the results for the algorithrn for the target district or management unit should be conducted. It does not need to be an exhaustive survey but can be a rapid field check. The test procedure should be documented. The algorithm for the district should be modified to reflect the results of this check. A timeframe should be fixed for these tasks. Different versions of the matrices and the maps should be organized. Only the most recent versions should be retained and they should be dated. Deviations from original 'approximations' could be documented if desired. Similarly the FOMAP regional map should not be retained if it serves no purpose because it does not reflect the current data base and could be misleading. An alternative would be to update the current map with a new legend and new symbols and values.

5.5 FOMAP-E

FOMAP-E is a priorization model which relatively ranks forest management areas (forest terrain units or combinations of units) on the basis of economic criteria. It is a decision-making tool designed to facilitate forest management planning by identifying those sites which offer the best return on silvicultural investment. It assists in deciding where to concentrate forest management dollars to realize the best return on investment, but does not question whether forest management is justified as an investment. It assumes prescriptions provided by unit foresters are optimal for given site conditions. Economic conditions remain constant. The model ranks sites based on gross merchantable volume of the future forest and integrates factors of productivity, location, technical ability to perform treatment, timing of dollar flows accruing to and from forest lands, and demand.

The Regional Forest Economist, S. Teskey (1985), stated that the **objective** of the model was to provide a practical field tool "to reduce the complexity and to enhance the consistency and effectiveness of the forest management decision-making process."

5.5.1 Assumptions

The project was conducted based on the following assumptions:

1. growth curves of managed stands follow the same general pattern by site class and site region as natural stands and simply have steeper slopes;

2. managed stands produce the same yields over shorter rotations;

3. forest land is defined by a maximum gross total volume capacity; forest management may increase merchantable volumes at harvest but it is unlikely to enhance the gross total fiber carrying capacity of site;

4. intermediate harvests prescribed to capture fiber loss due to mortality, actually reduce stocking therefore total fiber yield over time;

5. species composition is constant over the rotation (the model uses the species composition of a projected final harvest).

The following information was required to implement and use the model:

1. site information/productivity: based on NE Region's forest land productivity survey;

2. silvicultural prescriptions: based on FLaPS site information, provided by the unit forester; probability of need associated with each treatment;

3. wood flow: destination of pulp and sawlogs by township based on current wood flow;

4. treatment costs: from silvicultural records 1977/78 and 1982/83, inflated to 1983 dollars; key site parameters identified by step-wise regression;

5. value added/cubic metres: from Statistics Canada data, present product mix and consumption volumes from mill returns using the five year averages.

5.5.2 Methods

The methods were clearly described by Teskey (1985). The program is written in BASIC on the Radio Shack TRS-80 model 16 operating under the Xenix system with one section (4) written in the programming language on a DEC PRO 350. Users can adjust model parameters for individual management units. The model:

1) determines weighted average cost per ha of various silvicultural treatments,

2) projects fiber yields expected from FOMAP unit based on the management series, prescribed,

3) determines return on investment from each unit, and

4) assigns priorities for forest management.

A separate model was developed to test the sensitivity of model parameters, and was tested on North Bay district data.

5.5.3 Initial Results

Economic ranking increased with increased yield, shorter rotation and increased thinnings. Harvest penalties (eg. hauling distance) did not significantly reduce economic ranking. Ranking differed from FOMAP classes because unit foresters selected species and management intensity independently of FOMAP ranking methods.

Equivalent annuity (EA) classes related to the regional growth and yield data set were as follows (OMNR 1984):

Equivalent Annuity ($/ha/yr)	Site Region	Site Class	Species
400-500	5E	1	Pr, pure and mixed
250-400	5E	1	Pw, Sw, Pj with large Pr component
	4E, 5E	1	Pj, Po
100-250	4E, 5E		mixed units
	4E	1	Pr
	5E	1	Pw
0-100	all		Sw
	4E	1	Pw
	4E, 5E	1	Sb
	4E, 5E	2,3,4	all species except Sb
< 0	All	2,3,4	Sb

Yield Determination

Yield was projected in four stages:

i) soliciting prescription from unit forester;
ii) determining FOMAP soil data;
iii) matching site to prescription;
iv) projecting yield by species at harvest.

A locally developed yield determination program (HARVVOL) was used. It determined the soil data for the unit under analysis. A FOMAP unit was matched to a corresponding FLaPS terrain unit and the data from existing computer files was extracted. Each 10% soil component of a unit was assigned an appropriate prescription based on soil types. This was stored in files named 'soilpresc' by district. Yield determinations were based on prescribed species and site region. A site class was determined by township for each area and gross total volume at rotation was determined from the FLaPS volume tables as interpreted by Kroetsch (1982). Rotation age was determined at maximum gross merchantable mean annual increment under natural stand conditions. Volumes were straight-lined if the rotation fell between volume table age increments. Because the volume tables used were based on variable stocking, no additional stocking factor was introduced. A weighted average GTV by species was calculated for the unit as a whole.

The first file 'INTMDNPV' lists site region and site class for each soil component by township and includes key site parameters influencing treatment costs (slope and stoniness). A second file (HARVOL) lists weighted average gross total volume per hectare by FOMAP unit, site region, prescription and species.

Return analysis

The program converts natural yields to yields under management by adjusting the timing of treatments. It converts gross total volume to gross merchantable volumes based on site class, species, and age and determines cost and revenues. A prorated volume ratio based on the rotation age from the associated prescription was multiplied by the natural yield at a given age to convert it to the yield expected under management. Teskey (1985) describes the methods used in some detail.

Gross Merchantable Adjustments

Gross total volumes were converted to gross merchantable volumes by applying a GMV/GTV factor to yields. Gross total yields under management were multiplied by the GMV/GTV factor corresponding to the age at which natural unmanaged stands would attain the same volume. A 75% relative utilization factor was applied against hardwood volumes to reflect greater bush waste associated with their harvest.

Sensitivity Analysis

The major factors influencing the magnitude of the calculated equivalent annuity values were the maximum mean annual increment and harvest timings, except where a species was heavily thinned or rotations were significantly shortened.

5.5.4 Limitations

Two limitations identified by Teskey (1985) are arbitrary up-front assumptions and subjectivity of the methods. The application of discounting costs and benefits was weak because the data on demand and the comparison of alternatives were only approximations. A high degree of aggregation was used.

FOMAP-E failed to model the existing forest and therefore it did not model wood supply realistically. It did not allow regeneration prescriptions to be modified to meet shortfalls in supply that were identified.

Recommended Modifications related to Growth and Yield Data

i) GMV/GTV ratios: These ratios should be based on pre-adjusted ages to align top/stump ratios with volume rather that age. Where Gross total volumes are not available at rotation age from FLaPS volume tables, gross total volume should be calculated by dividing gross merchantable volume from actual GMV/GTV smoothed curves instead of using a standard .85 ratio. Smoothed curve values should replace actual GMV/GTV ratios currently used.

ii) FLaPS volumes: Updated volume tables should be used rather that the 1982

version. Where early age classes show no volume, volumes extrapolated by drawing a straight line to the origin should replace values in the model.

iii) Currently white spruce prescriptions are not identified in HARVVOL files. They should be added if the model is to be used.

iv) FOMAP ratings should be refined.

v) Red pine prescriptions and volumes were used to estimate tolerant hardwood values. Use tolerant hardwood volume tables. Species prescriptions should be developed for appropriate sites.

vi) The model searches adjacent townships within but not between districts for a FOMAP unit that crosses boundaries.

Please refer to Teskey (1985) for other recommended modifications. She lists 19 suggestions.

5.6 MODEL 1 SIAM (SILVICULTURAL INVESTMENT ANALYSIS MODEL)

For a detailed discussion of SIAM the reader is referred to the document 'Implementing PriSMa in the 1990 Timber Management Plans' (OMNR 1988). Reports are filed on the economic analysis program, and documentation that accompanies the SIAM model. The discussion in this report will only briefly highlight the application of the growth and yield data set to this model.

SIAM was designed to provide a systematic means for comparing various silvicultural options for operational groups. It helps foresters analyze the economics of regenerating a forest while considering the productive potential of the site based on soil- and site-related growth and yield data, and the ease of management. Ease-of-management considerations are related to defined topography, stoniness, texture, depth and moisture classes. No species was assumed to be preferred based on FLaPS Species Selection Matrix in this model and no level of management is predetermined to be appropriate as per the FOMAP matrix. The model is a menu-driven program designed to provide a standardized framework for defining operational groups and assigning silvicultural prescriptions to each group.

The output is expressed as an equivalent annuity.

The model needs the following inputs:

- specifications for alternative means of obtaining future crops, including possible forest conversion (silvicultural alternatives);

- merchantable yield of the future crops and its value (expected future stand stocking and species composition including assignment of NE region site class based on FLaPS growth and yield data sets);

- cost of specified silvicultural operations;

- probability that treatments are required and probability of success, ie. the probability that a treatment is required for a given operational group defined by topography, stoniness, texture, depth and moisture; the expected regeneration success of the treatment on the defined sites.

The forester develops silvicultural prescriptions for obtaining new crops for operational crops within forest units. Forest units are established by refining working group by assigning a site class to the WG (current procedures assign the site class by relating FRI height and age data to NE Region site class height/age ranges using the Timer Management Planning Toolbox). A Forest Unit thus represents an aggregate of stands with similar growth potential and forest composition. Each Forest Unit is divided into operable and inoperable areas based on stoniness and topography. Texture, depth and moisture attributes are generated from preliminary data files that summarize the soils by stand. These attribute files are developed by the local forest managers using local knowledge, and available soil maps or air photo interpretation, or both.

The Timber Management Planning Toolbox (dBase II) can be used to summarize soil conditions for the operational groups, providing that data files have been developed. Operational groups are divisions of Forest Units according to operability based on topography and stoniness, and further divided on the basis of soil texture, depth and moisture where applicable. SIAM permits the forester to modify operational group descriptions for a specific forest unit to permit specific

prescriptions to be made for smaller areas (Babour 1989). SIAM draws on the summaries as an input factor; it does not compare prescriptions on a stand-by-stand basis but rather by operational group. Discounted benefits and costs are used as measures for comparing alternatives. The economic index generated by the model are expressed as Equivalent Annuity calculated from discounted costs and benefits. Outputs of SIAM include summaries of expected yields and economic returns; thinning and harvest yields by species and product; discounted silvicultural costs; discounted revenues; net equivalent annuity (revenue minus cost); harvesting cycles and systems and a summary of silvicultural operations (NE Region PriSMa Summary 1988, p. 11).

Rotation ages are defined using the NE Region yield tables with merchantable yield by product, and other sources of information. The maximum annual depletion is calculated for the Forest Units. Each Forest Unit is managed under one broad silvicultural system. Future yields can be estimated for each Forest Unit as each implies similar yield. Silviculture treatments can be analyzed and compared economically.

5.7 MODEL 2

Model 2 was designed to help the forester evaluate stand harvesting priorities in economic terms. It was developed by P. Babour in 1987-88 in conjunction with SIAM. The project was carried out partly in response to the Baskerville audit calling for more accountability in investment of funds for silviculture and in achievement of forest management objectives. Both models were developed in conjunction with the Tomiko Pilot Project of the NE Region PriSMa program.

The input for the model is the prescription generated from SIAM for operational groups. The input consists of either the optimum or sub-optimum prescription, in terms of returns on investment. This takes into account other criteria for selecting a silvicultural prescription for a given stand and permits modified-cutting options that may not generate the highest economic return in terms of fiber acquisition. Prescriptions organized by operational group are assigned to specific stands. The model evaluated forest potential relative to demand.

Model 2 is designed to assign harvesting priorities to individual stands, in contrast

to FOMAP-E which assigned priorities to FLaPS terrain units. Once the operational group to which the stand belongs and the associated silvicultural treatment regime (derived with model) for the future forest is identified the stand becomes the unit of analysis. Stand information including current stand yield, projected future stand yield, regeneration priority in terms of returns on investment, access category (amount of road needed for a stand) and other land use constraints is summarized in table format.

The 'stand' is the basic unit for which management alternatives are examined in model 2 (Babour 1989, draft, p. 5). Worksheets allow the forester to explore alternative means of meeting short-term demand levels efficiently. Long-term simulation procedures provide summaries which allow the forester to check whether yields will be sustainable based on the data. The model is interactive. It allows comparisons between two or more access routes with the potential to include hauling costs and to identify stands for species conversion.

The model works with individual stands rather that age classes or broader classifications of land. It considers stand location.

Limitations

Model output depends on the reliability of projected yield (based on NE Region growth and yield data), current stand descriptions (FRI and Operational Cruise Data), site (soil and terrain descriptions for each stand) and cost data for management activities and product values.

5.8 PRIME SITE PROGRAM (PriSMa) 1988 RELATED TO MANAGEMENT PLANNING AND TO THE NE REGION FLaPS GROWTH AND YIELD DATA

A concise summary of the NE Prime Site Management program in relation to management planning is available (NE Region 1988; file report). Both SIAM (model 1) and model 2 (harvest priorities model) were developed as tools for implementing PriSMa principles in management planning (Tomiko Pilot project). As such the relationship of the PriSMa program to the NE Region FLaPS growth and yield data has largely been covered in the summary of these programs.

5.8.1 Purpose

The **objective** of the NE Region's PriSMa program has recently been defined as "to get the best return on investment" (OMNR 1988 (Implementing PriSMa in the 1990 Timber Management Plans: NER PriSMa 1988 p. 1)) A broader definition of the program is given in the NE Region Forest Site Evaluation Manual (Kershaw 1988).

5.8.2 Assumptions

The underlying assumptions of the PriSMa program are that forest productivity is related to forest site characteristics and that the relationship can be predicted for practical applications, based on field inventory data and simple models. A further assumption is that costs of operations vary with site and species and that these variations can be quantified. In assessing the value of future yields rotation ages are assumed to reflect the land's ability to produce a product. This in turn affects the MAD value.

Most silvicultural investments follow the harvest. The harvest schedule thus affects the silvicultural investment possibilities. It is further presupposed that economic analysis enhances the effectiveness and credibility of forest management decisions. Economic models are assumed to able to assist in setting harvesting priorities and directing the harvest to land with greater return on investments. It is assumed that economic and biophysical analyses can contribute to selecting optimal silvicultural prescriptions.

5.8.3 Methods

PriSMa procedures for management planning are divided into three general stages:

a) the forest subdivision phase (Forest Unit formation);

b) silviculture prescription phase;

c) harvest scheduling phase (not discussed here because it is part of Model 2, which is not yet working).

Forest Subdivision (Forest Unit Formation)

The production forest is divided into Forest Unit (FU) based on working groups, NER FLaPS site classes, and occasionally species composition. The FU represents an aggregate of stands with similar growth potential and forest composition. The Forest Unit is the smallest aggregated forest division for which a maximum allowable depletion is calculated. The division of WG into FU based on yield potential is important in guiding silvicultural investment. Forest site (type and quality of vegetation an area can carry) and the relative ease of managing sites (operational constraints due to topography, stoniness and moisture conditions) must be understood when prescribing where and how to carry out silviculture.

Site class is calculated for each production forest stand (free-to-grow stand) by relating FRI height and age to NE Region site class height/age ranges. The dBASE version of the Timber Management Planning toolbox will perform this operation and revise stand stocking.

The NE Region site class for barren and scattered (B+S) and not sufficiently regenerated stands (NSR) is assigned. This will allow one to determine how much area is barren and scattered, and how much not sufficiently regenerated, for a particular working group by site class, and will assist in rationalizing silvicultural renewal or maintenance.

<u>Option 1:</u> Overlay B+S and NSR stands with soil maps to estimate a site class based on texture, depth and moisture;

<u>Option 2:</u> Pro-rate the same site class distribution as for free-to-grow forest (by weighting the estimate);

<u>Option 3:</u> Ignore B+S; prepare a working group summary.

Produce age class summaries for each working group by site class to review forest structure.

Form forest units based on working group and site class grouping where reasonable, and produce the age class distribution for each Forest Unit, making sure each forest unit is practical. It should be large enough to regulate, have more than one age class, and small and homogeneous enough to be manageable under one silvicultural system (eg. clearcut, shelterwood or selection).

Assign to each Forest Unit the NE Region yield curve that best represents yield in the Forest Unit. If the unit is based on a combination of WG and site classes you must assign a nominal working group and appropriate yield information. For example, take the weighted mean of the individual working group-site class and use the curve which matches the mean working group-site class.

Use the merchantable yield curves by product and other information to rationalize rotations for each Forest Unit.

Calculate the Maximum Allowable Depletion for each Forest Unit.

SECTION 6. EXECUTIVE SUMMARY OF DOCUMENTED RECOMMENDATIONS AND LIMITATIONS

Audit of Growth and Yield Soils Data 1984: Recommendations to review all raw soils data associated with each sampled tree and revise the soils data as required. Errors were encountered in soil depth, soil texture and soil moisture regime. Soils and site attributes assigned to each site class should be reviewed and modified as required. The species selection matrices should be revised.

Warren and Wood 1982. Warren and Wood recommended using all trees greater than 8 cm for the calculation of the tree of mean basal area, not just the species of interest. They also noted the need to emphasize freedom from defect in selecting trees. Height percentages and diameters of the nearest five neighbours should be recorded to better estimate competition and to assess the tree of mean basal area.

A revised method for rating moisture regime for very shallow sites should be developed. Ratings using the standard chart for deep soils appeared erroneous. More emphasis should be placed on describing the LFH layers, especially on very shallow sites. The texture of the B horizon and any texture stratifications should be recorded. Stoniness estimates should be improved and standardized. Position on slope should be recorded with more care to document microtopography. A cross-sectional profile of the plot location should be sketched. Moderately dry and fresh moisture regimes should be further refined because they are frequently transitional classes between two height groups.

Kroetsch 1982. The 1982 reworking of the AMIK growth and yield curves identified a weakness in the mortality curves. Stand densities for older stands should be based on statistically sound sampling. He identified a lack of information for white pine growing on very shallow and deep sites for site region 5E; no data for moist or wet sites, moderately deep fine loams and finer textured soils for red pine in site region 4E, and limited parameter definition for distinguishing site class II and III for red pine in site region 5E.

Collier 1984. Collier reviewed the FLaPS growth and yield procedures in 1984. The reader is referred to his report for a full discussion of the recommended modifications. The three key modifications recommended are plot sampling to

replace the selection of individual trees of mean basal area, improved collection of data on soils and ground vegetation, and using the polygon area method for collecting density data in mixed stands.

Collier 1985. In a critique of the FLaPS growth and yield procedures, Collier indicated that the purpose and objectives of the FLaPS growth and yield program should be clearly defined with a stated acceptable probability of error and a stated level of accuracy. The autecology of each species should be clearly understood and staff should be trained well.

Required computing resources, storage space and appropriate analytical software should be defined and acquired for the growth and yield program. Comprehensive documentation of data analysis, data format, and data storage should be mandatory for any further growth and yield work.

He recommends studying the feasibility of using the -3/2 power law for determining stand density in future studies. A mean tree growth model should be developed for each clearly defined site type. The volume-spacing function should be determined for each site type. Spacing should be determined from the growth model and yield tables produced.

Collier 1985. His reworking of the black spruce data identified many of the limitations noted by earlier workers. In addition he noted the need to collect data on the litter (LFH) layers as it may be a critical factor in determining site class. He also recommended testing the assumption that stands are even-aged for sampling using the current growth and yield methods. He also noted the need for improved soil data for each of the plots.

Collier 1985. In his work on jack pine in site region 3E Collier noted the need to develop a mechanism for dealing with rot in sampled trees. He also recommended using a measure of variability of the mean volume in the stand in FLaPS growth and yield procedures. He also warned of the use of the methods in mixed stands noting that there was no evidence to ensure that the samples would be representative of the volumes which could be supported. Collier reiterated the weakness in the yield functions.

Quist 1984. In this study on birch, no consistent measure of stocking for clumped stands was developed. No understocked stands were represented in the sample, yet conclusions about stocking were made. Reconnaissance data from the Wawa study displayed height differences up to 2 m yet these trees were integrated into the basic data set. These should be removed. Sample distribution was clumped, yet generalized conclusions were made for the region. Many site conditions were not represented in the sampling. The objectives of Quist's study should be confirmed, and should govern the application of its results. Stands were young and yield projections were subjective. Estimates of branch volume were weak.

Kershaw 1989: Species Selection Matrices and Yield Curves: The soil parameters in the species selection matrices should be re-examined. Kershaw (1988) re-examined a sample of the soil attribute assignments in an internal file document which demonstrated the need for revisions. The soil attribute assignments to the current yield curves should be reassessed and redefined. All applications should adopt the revisions. If no revisions are carried out, then the level of reliability and accuracy of the species selection matrices should be clearly defined. The species selected for each soil type in the matrices should be re-evaluated by each district and in some cases for each Management unit if the matrices are to be used for District and Management planning applications. Only the most up-to-date version of the matrices should be retained.

A forest productivity indicator does not account for differences in local site factors. For example it does not account for aspect, position on slope, proximity to a water body and historical factors such as stand development.

The FOMAP matrix is biased towards evaluating the ease of management for artificially regenerated species. It is weak in assessing the ease of management for natural regeneration. It does not take into account the current forest cover in an area, access or markets. It should be re-evaluated and revised if still needed.

The PRODMAPs and the regional FOMAP map should be archived. The data base from which these products were developed is out of date. The algorithm for redefining the FOMAP rating for each FLaPS soil unit was revised by Christilaw in 1988.

Soil/FRI/Species Selection assignment: The soil/FRI matching algorithm should be redefined for each district or management unit. Initially the changes recommended based on the Tomiko field PriSMa audit should be implemented. Should the algorithm be used as a framework for assigning a NE Region site class for management planning purposes, each district should perform a small field test of the algorithm's output.

Teskey 1985, p.44. Economic Model: FOMAP-E. Teskey made several recommendations:

i) GMV/GTV ratios: These ratios should be based on pre-adjusted ages to align top/stump ratios with volume rather than age. Where gross total volumes are not available at rotation age from FLaPS volume tables, the volumes should be extrapolated from the appropriate growth curves rather than by using a standard .85 ratio.

ii) FLaPS volumes: Updated volume tables should be used rather than the 1982 version. Where early age classes show no volume, volumes extrapolated by drawing a straight line through the origin should replace values in the model.

iii) Currently the HARVVOL files contain no white spruce prescriptions. They should be added if the model is to be used.

iv) FOMAP ratings should be refined.

v) Red pine prescriptions and volumes were used to estimate tolerant hardwood values. Tolerant hardwood volume tables should be used. Species prescriptions should be developed for appropriate sites.

vi) The model searches adjacent townships within but not between districts for a FOMAP unit that crosses boundaries.

Leale and Babour 1988. SIAM These authors identify a number of limitations in various file notes. Of primary concern is the need to re-evaluate the species selection matrices, the soil attributes assigned to each site class and the density curves used to develop the yield curves. They note additional weaknesses

including product definition and costing data. The absence of a reliable data set for hardwoods is also discussed.

SELECTED REFERENCES

Barbour P. 1989. (untitled) Draft documentation of Model 2. Stand harvest allocation model (no page no.)

Benson, C.A. 1976. Assessment of productive areas and soil mapping for the management units for the Northeastern Region of the Ontario Ministry of Natural Resources (unpubl. rep.)

Collier, R.L. 1985. A preliminary analysis of the data collected from a jack pine stand by White River. F.La.P.S. NE Region file report 0718

Collier, R.L. 1985. FLaPS NER growth and yield procedures - a critique. 4p.

Collier, R.L. Jan 1985. Suggested sampling procedure for coppice-origin stands within the forest land productivity survey program, NE region. 3 p. (library 0720)

Collier, R.L. Mar. 1985. A methodology for producing forest yield tables. Forest land productivity survey, Northeastern Region. 12p. (library 0720)

Collier, R.L. Dec. 1984. Procedure for developing site index for the forest land productivity survey. 2p.

Collier, R.L. Feb. 1985. Procedure for determining trees per hectare over time. FLaPS NE Region (library 0720)

Collier, R.L. June 1985. Yield tables for black spruce growing in site region 3E, Forest Land Productivity Survey (FLaPS). 46 p. (library 0717)

Hauer, G. 1982. Summary of white birch, yellow birch and hard maple growth study for Wawa District (on file, file not numbered); use of stem analysis programs 'stemdig' and 'stemvol' is documented; data stored on Model 16 TRS-80 computer; data used to construct growth curves.

Heaman, D. April 22, 1987. A review of the hardwood growth and yield study, North Bay, 1986. 10 p.

Heikurinen, J.K. and A. Slater. 1978. Spanish River productivity survey. OMNR Sudbury file report.

Heikurinen, J.K. 1985. FLaPS growth and yield survey - an overview.

Heikurinen, J.K. and H.M. Kershaw. 1986. Forest soils as a management framework: the data base. In 'Site Classification in Relation to Forest Management' COJFRC Symposium Proceedings, O-P-14 p.95-103

Heikurinen, J.K. and H.M. Kershaw. 1986. Forest soils as a management framework: The application. In 'Site Classification in Relation to Forest Management' COJFRC Symposium Procedings, O-P-14, p.104-112

Hill, C.A. 1960. Regional site research. For. Chron. 36: 401-433s

Kershaw, H.M. 1984. Growth and yield survey: executive summary 4p.

Kershaw, H.M. 1988.(compiler) NE Region Volume 1. Forest Site Evaluation Manual. Ont. Ministry of Natural Resources, NE Region.

Kloss, D. Aug. 1983. Fitting growth curves to data: a documentation of the programmes used; OMNR NE Region FLaPS. (library file 11.4.3)

Kroetsch, J. 1982. Summary of soils data and growth and yield data to redefine height-over-age and volume-over-age curves for site and height classes independent of the soil depth strata (file report in binder format).

Kroetsch, J. 1982. Summary of red pine and white pine growth and yield data for site region 4200 and 5200 for application by Temagami District in reassessing rotation ages (file report, binder)

Leale, C.J. (compiler) 1988. Northeastern Region yield tables for major species.

NE Region, 1982. Black spruce growth and yield data as part of peatland survey (data integrated with main NE Region growth and yield data set; printouts filed under spruce by site region).

Niemi, C. 1984. Relocation of growth and yield plots for reanalysis of soils data (audit report, on file).

Niemi, C. and R. Collier 1984. Recommended modifications for the forest land productivity survey. (library 0726) 5p.

Ontario Ministry of Natural Resources, 1978. Contract Specifications with AMIK for FLaPS Growth and Yield survey.

OMNR, NE Region, Oct. 31, 1984. Priorization model for forest management areas in the Northeastern Region; initial test results October 31, 1984 7p. (by S. Teskey, Regional Forest Economist).

OMNR: 1983 Reference Manual for the 1:15,840 OMNR NER Forest Soil Survey Manual. 161 p.

OMNR: 1984 Forest Soil Survey Procedure Manual for the 1:15,840 scale mapping.

OMNR: 1988. Implementing PriSMa in the 1990 Timber Management Plans: NER PriSMa Procedures 1988.

Plonski, W. 1984. Normal yield tables (metric) for major forest species of Ontario. Ont. Min. Nat. Resour. Toronto, Ontario.

Quist, 1984. Preliminary analysis of white birch stem analysis program, internal file report.

Spurr and Barnes, 1973. Forest ecology. The Ronald Press Co. New York 571 p.

Teskey, S. 1985. Northeastern Region's Forest Management Economic Priorities Model. 56p.

Warren and Wood, 1981. The Forest Land Productivity Survey: Preliminary Analysis of 1980 Growth and Yield Data, AMIK forestry consultants.

Warren and Wood, 1982. The Forest Land Productivity Survey Growth and Yield Data, AMIK forestry consultants.

APPENDIX I

1985 Summary of NE Region's Growth and Yield Data Base by Site Region and Species

1985 Summary of NE Region's Growth and Yield Data Base by Site Region and Species

(number of trees sampled)

Site Region	3E	4E	5E	NER
Species				
Red Pine		119	103	222
White Pine		70	61	131
Jack Pine	175	110		285
White Spruce	28?[a]	16	8	52
Black Spruce	61	48(128-4/5)	80[b]	189
Poplar	28?[c]	43	79	169
White Birch	60	6		120
Yellow Birch		29	12	41
Hard Maple		24	20	44
TOTAL				1153

[a] Interpolated from the regional total and the site-regional subtotals.

[b] Interpolated from a record stating that the total for 4E and 5E was 128 trees.

[c] Only 28 trees for poplar 3E were found by this author, but a total of 90 trees for 3E and 4E is on record elsewhere.

APPENDIX II

Summary of Tree Growth Trends Related to Site Factors by Species

Summary of Tree Growth Trends Related to Site Factors by Species (Kroetsch, 1982)

(continued next page)

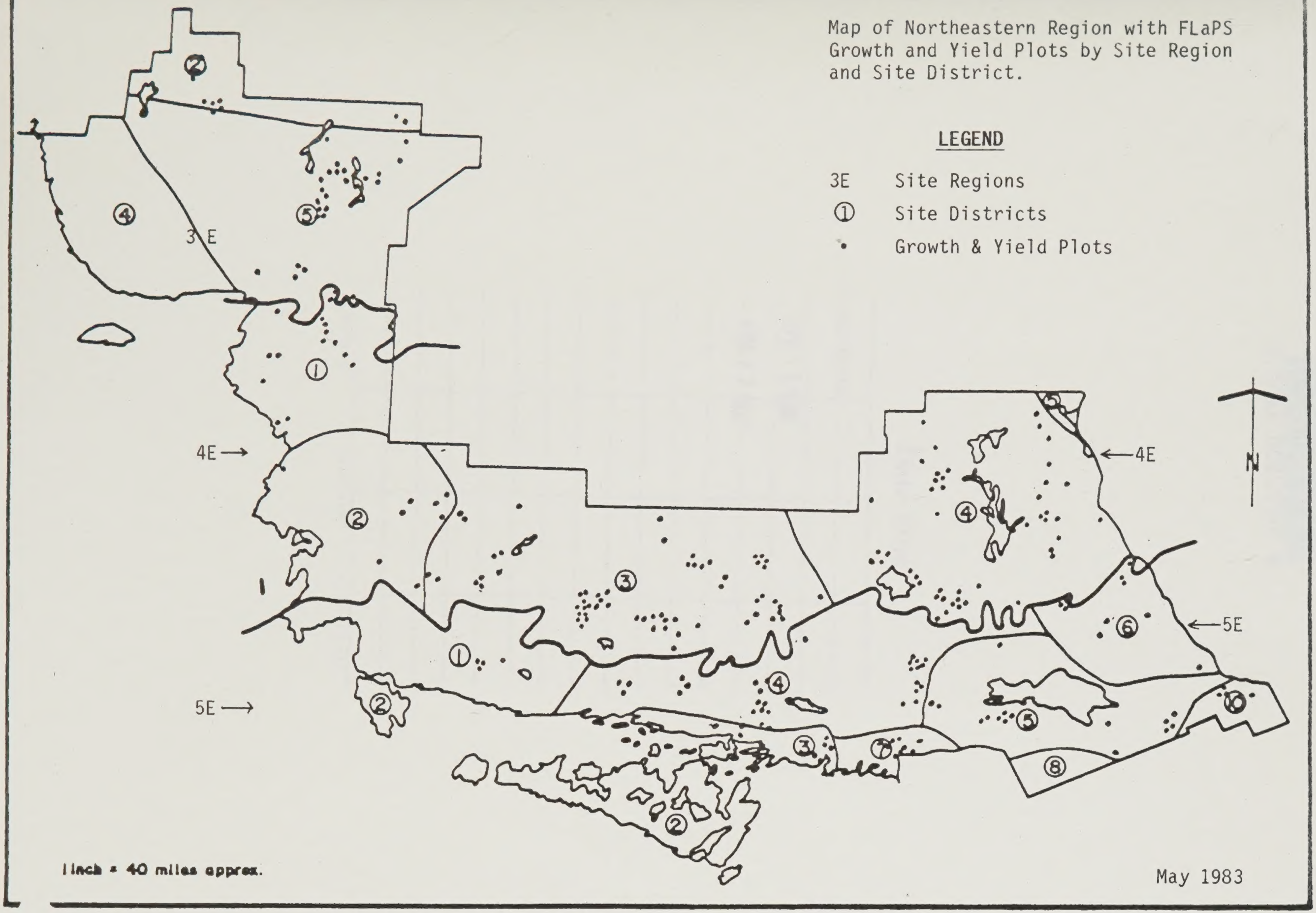
				Assessed for Each Tree			Assessed per Plot				
Species	Site Region	No. Plots	No. Trees	Texture	Moisture	Depth	Aspect	Position on Slope	% Slope	Organic Matter 20 cm	General Comments
Pw	4200	20	66	SaLo< vfSa		>120 Best					Most Plots on Severe W & E Crest to Midslope Positions
	5200	21	61	Cl/Lo<Sa	vfSa may be poorer	only 6 trees >120		No Base	Severe Crest OK	N.A.	
Pr	4200	32	119	Cl cSa	Few D	>120 cm				N.A.	
	5200	31	102	f,cSa Better		>120 Best					
Pj	3200	26	98	cSa SiSa (No SiCl)	F > D	>120 Best	30 - 120 cm		Crest Poor	N.A.	Good Range of Sites
	4200	38	133	No Si-Cl		>120 Best	No N. dD	No Base	Steep Slope Crest Poor	N.A.	Majority of Sites on Level Sites
	5200	21	80				Only Sw,S,L	No Base 1 Crest	Only 0-5°	N.A.	All Sites Level to 5° Slope

APPENDIX II continued

				Assessed for Each Tree			Assessed per Plot				
Species	Site Region	No. Plots	No. Trees	Texture	Moisture	Depth	Aspect	Position on Slope	% Slope	Organic Matter 20 cm	General Comments
Po	3200 4200	29	108	Sa< Lo/Cl	Few D	No vS				N.A.	
	5200	27	105					9 Plots Incomplete			Position on Slope & Moisture Most Important
Sb	3200	16	61					Level Poor		Related to Soil Moisture	
	4200 5200	35	134							Related to Soil Moisture	Majority are Level Sites
Sw	3200 4200 5200	15	50	Esp. >120 cm		Not Alone		Base of Slope Best		N.A.	Insufficient Data to Show Site Regional Differences

APPENDIX III

Map of Northeastern Region with FLaPS growth and yield plots by site regions and site districts



Map of Northeastern Region with FLaPS Growth and Yield Plots by Site Region and Site District.